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DRAFT

Work Plan for an Engineering Evaluation/Cost Analysis in Support of the Intrinsic Remediation (Natural Attenuation) Option at the Former Fire Protection Training Area No. 4



**Pope Air Force Base
Fayetteville, North Carolina**

Prepared For

**Air Force Center for Environmental Excellence
Brooks Air Force Base
San Antonio, Texas**

and

**Pope Air Force Base
Fayetteville, North Carolina**

April 1995



**PARSONS
ENGINEERING SCIENCE, INC.**

1700 Broadway, Suite 900 • Denver, Colorado 80290

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WORK PLAN FOR AN
ENGINEERING EVALUATION/COST ANALYSIS
IN SUPPORT OF THE INTRINSIC REMEDIATION
(NATURAL ATTENUATION) OPTION
AT THE FORMER FIRE PROTECTION TRAINING AREA No. 4
POPE AIR FORCE BASE
FAYETTEVILLE, NORTH CAROLINA

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE
SAN ANTONIO, TEXAS

AND

POPE AIR FORCE BASE
FAYETTEVILLE, NORTH CAROLINA

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April 1995

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SECTION 1

INTRODUCTION

This work plan, prepared by Parsons Engineering Science, Inc. (Parsons ES), presents the scope of work required for the collection of data necessary to conduct an engineering evaluation/cost analysis (EE/CA) for remediation of groundwater contaminated with petroleum products at the former Fire Protection Training Area (FPTA) No. 4 located at Pope Air Force Base (AFB), Fayetteville, North Carolina. Several remedial options will be evaluated during the EE/CA possibly including continued free product removal; groundwater extraction, treatment, and reinjection (i.e., pump and treat); air sparging; and natural contaminant attenuation (intrinsic remediation) with long-term monitoring. All hydrogeologic and groundwater chemical data necessary to evaluate the various remedial options will be collected under this program. However, this work plan is oriented toward the collection of hydrogeologic data to be used in support of intrinsic remediation for restoration of fuel-hydrocarbon-contaminated groundwater. When applicable, site-specific information may be obtained from previous studies conducted at Pope AFB.

Data collected during the field effort will also be used as input to the Bioplume II model code. As part of the EE/CA, the Bioplume II modeling effort has three primary objectives: 1) to predict the future extent and concentration of the dissolved-phase contaminant plume by modeling the effects of advection, dispersion, sorption, and biodegradation; 2) to assess the possible risk to potential downgradient receptors; and 3) to provide technical support for selection of the intrinsic remediation option as the best remedial alternative at regulatory negotiations, as appropriate. The Bioplume II modeling effort for this site involves completion of several tasks which are described in the following sections of this work plan.

This work plan was based on the statement of work (SOW) for this project, site-specific data from existing characterization reports, and discussions among representatives from U.S. Air Force Center for Environmental Excellence (AFCEE), Pope AFB, the North Carolina Division of Environmental Management Fayetteville Regional Office (DEM), and Parsons ES at a meeting at Pope AFB on March 28, 1995. All field work will follow the health and safety procedures presented in the program *Health and Safety Plan for Bioplume II Modeling Initiative* (ES, 1993) and the

site-specific addendum to the program Health and Safety Plan. This work plan was prepared for AFCEE and Pope AFB.

1.1 SCOPE OF CURRENT WORK PLAN

The ultimate objective of the work described herein is to provide an EE/CA for remediation of groundwater contamination at FPTA No. 4 located at Pope AFB. However, this project is part of a larger, broad-based initiative being conducted by AFCEE, in conjunction with the U.S. Environmental Protection Agency (EPA) and Parsons ES, to document the biodegradation and resulting attenuation of fuel hydrocarbons dissolved in groundwater, and to model this degradation using the Bioplume II numerical groundwater model. For this reason, the activities described in this work plan are directed toward the collection of data in support of this initiative. All data required to develop a 30-percent design of an alternate remediation system, should intrinsic remediation not prove to be a viable remedial option at this facility, will also be collected under this program. This work plan describes the site characterization activities which will be performed by Parsons ES and the USEPA's Robert S. Kerr Environmental Research Laboratory (RSKERL) in support of the EE/CA and the groundwater modeling effort.

Proposed site characterization activities include Geoprobe® testing, monitoring point placement, soil and groundwater sampling, and aquifer testing. The materials and methodologies required for collection of these data are described herein. Existing site-specific data and data collected during the supplemental site characterization activities described in this work plan will be used as input for the Bioplume II model. Where site-specific data are not available, conservative values for the types of aquifer materials present at the site will be obtained from widely accepted published literature and used for model input. Sensitivity analyses will be conducted for the parameters which are known to have the greatest influence on the results of Bioplume II modeling, and where possible, the model will be calibrated to historical site data. Upon completion of the Bioplume II model, Parsons ES will provide technical assistance at regulatory negotiations to support the intrinsic remediation option if the results of the modeling indicate that this approach is warranted. If it is shown that intrinsic remediation is not the most appropriate remedial option, Parsons ES will recommend the most appropriate groundwater remedial technology based on available data.

This work plan consists of six sections, including this introduction. Section 2 presents a review of existing site-specific data and a conceptual model for the site. Section 3 describes the proposed sampling strategy and procedures to be used for the collection of additional site characterization data. Section 4 describes the remedial option evaluation procedure and EE/CA report format. Section 5 describes the quality assurance/quality control (QA/QC) measures to be used during this project. Section 6 contains the references used in preparing this document. Appendix A contains soil analytical data from previous investigations. Appendix B contains groundwater analytical data from previous investigations. Appendix C contains a listing of the containers, preservatives, packaging, and shipping requirements for groundwater samples.

1.2 SITE BACKGROUND

Pope AFB is located in Cumberland County, North Carolina, near the city of Fayetteville and approximately 50 miles south-southwest of Raleigh. The base is bounded on the northwest by the Little River, on the north by residential and undeveloped land, to the east by the town of Spring Lake, and on the west and south by Fort Bragg Military Reservation. The city of Fayetteville, NC is located approximately 10 miles to the southeast of Pope AFB. Figure 1.1 is a regional location map showing the position of Pope AFB relative to the surrounding area. Pope AFB contains approximately 1,869 acres of land on the main base area.

The primary mission of Pope AFB is to provide airlift and tactical support for Fort Bragg. Pope AFB consists of a single runway, associated taxiways, airfield support facilities, offices, barracks, and military support facilities.

FPTA No. 4 is located near the southern boundary of the base, along Hurst Drive (Figure 1.2). The site covers approximately 6 acres and consists of four areas that are potential sources of subsurface contamination. Three of four areas are shown on Figure 1.3. A concrete-lined burning area was used from the early 1960s to 1990; an unlined burning area was used during the same time period; an aircraft mockup burning area (not shown) was used in the 1950s and early 1960s; and a sludge disposal pit for petroleum, oil, and lubricant (POL) was used during the 1950s (Metcalf & Eddy, 1992). Materials burned at the FPTA No. 4 included contaminated JP-4, diesel fuel, AVGAS, thinners, paints, alcohols, waste oils, hydraulic fluids, and transmission fluids

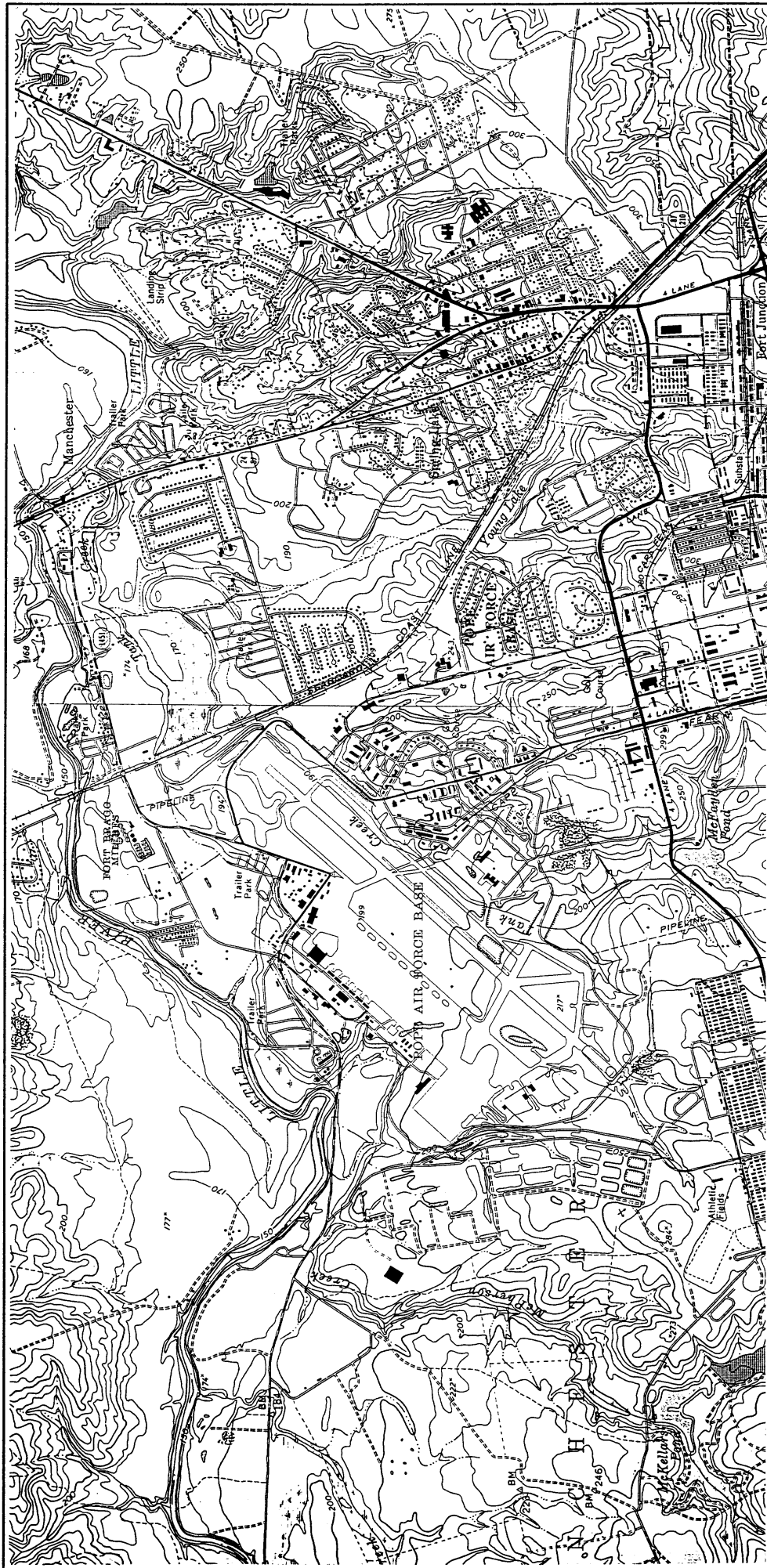
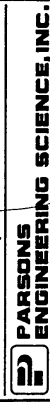


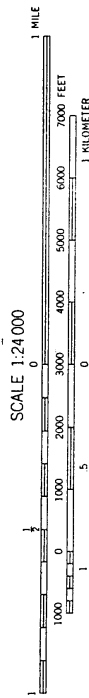
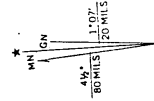
FIGURE 11

REGIONAL LOCATION MAP OF POPE AFB

Intrinalc Remediation EE/CA
FPTA No. 4
Pope AFB, NC



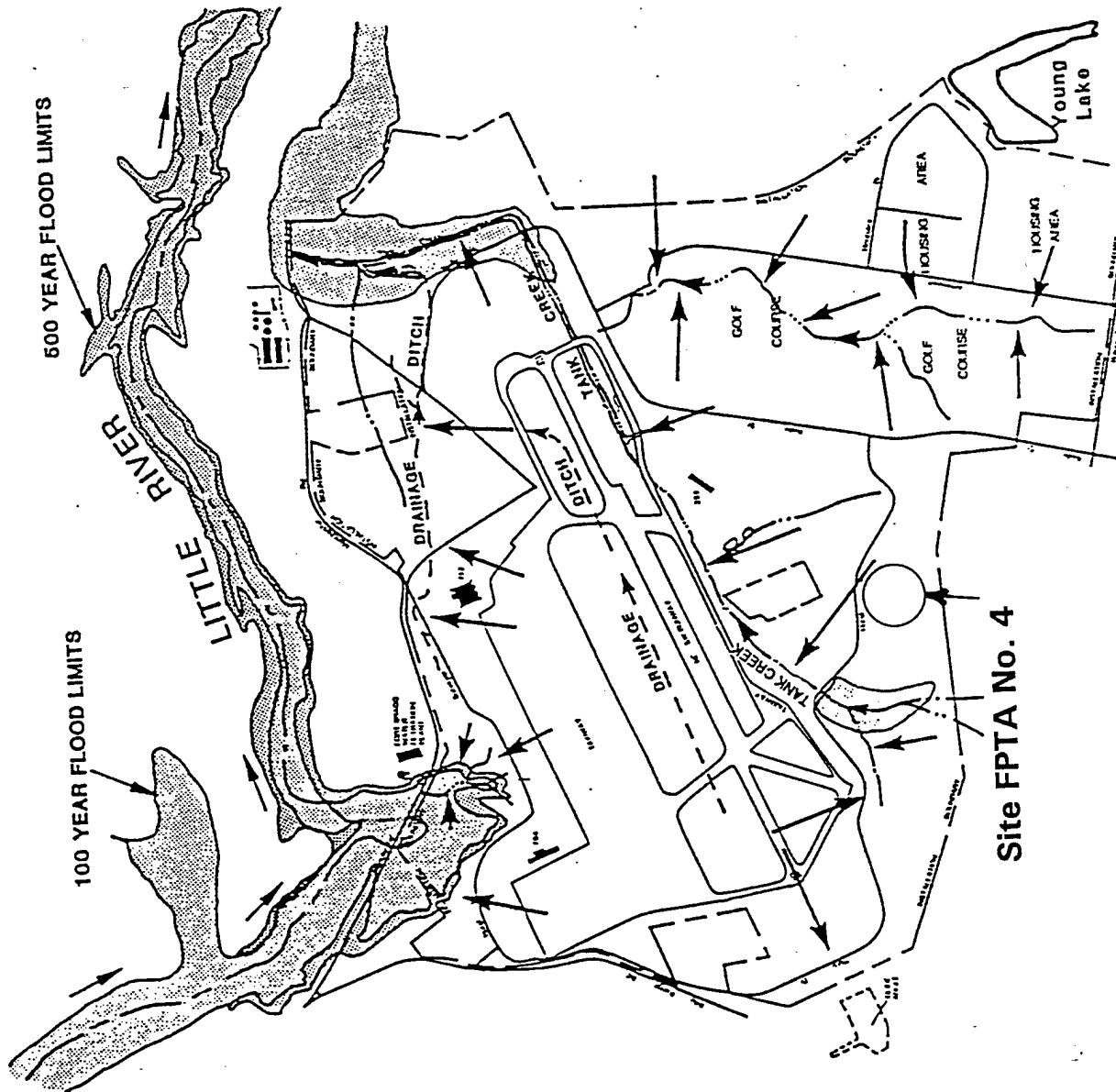
Cary, North Carolina



SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL



Sources:
USGS Overhills, NC Quadrangle, 1971
USGS Manchester, NC Quadrangle, 1987



LEGEND

- DIRECTION OF OVERLAND FLOW
- ▨ 100 YEAR FLOOD
- ▩ 500 YEAR FLOOD

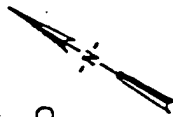


FIGURE 1.2

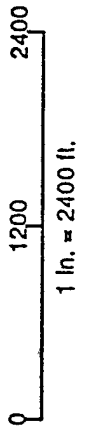
**POPE AFB
SITE MAP**

Intrinsic Remediation EE/CA
FPTA No. 4
Pope AFB, NC



Cary, North Carolina

Site FPTA No. 4



Source: Metcalf & Eddy, 1992.

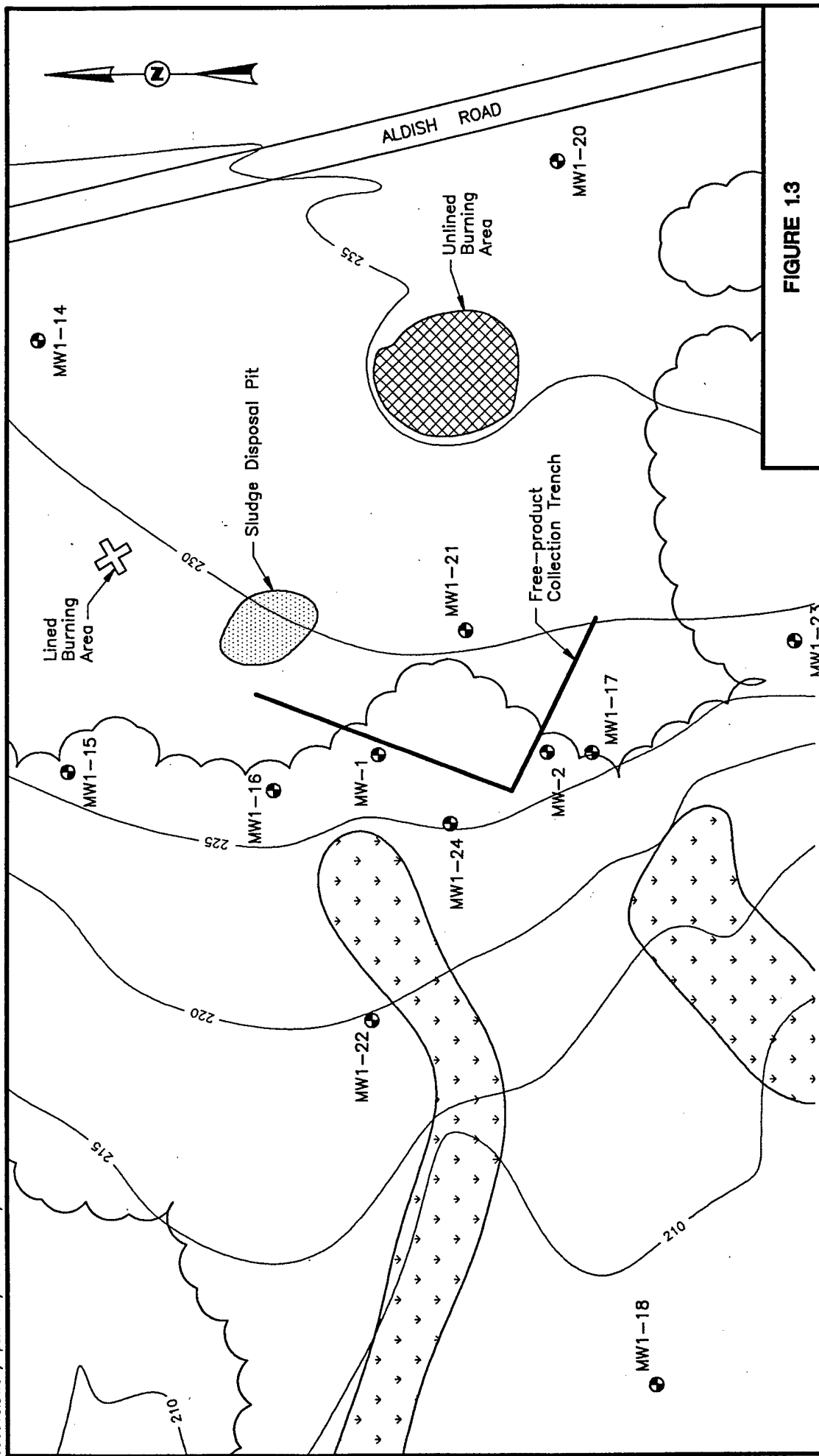


FIGURE 13
FIRE PROTECTION AREA NO. 4
SITE MAP

Intrinsic Remediation EE/CA
FPTA No. 4
Pope AFB, NC



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Cary, North Carolina

LEGEND

- Monitoring well.
- 225 — Topographic contour (feet above mean sea level).
- [Pattern] Estimated areal extent of wetlands.



Source: Metcalf & Eddy, 1992.

(Metcalf & Eddy, 1992). By the mid-1970s, waste fuels were the main materials burned (Metcalf & Eddy, 1992).

Site investigations have been performed at FPTA No. 4 in several phases. In 1989, a soil gas survey and geophysical survey were performed to identify areas of subsurface contamination and potential buried objects (such as drums). Soil, groundwater, surface water, and sediment sampling was performed during Phase I investigations at the site in 1989 and 1990. Phase 2 Site Investigation activities performed in 1991 and 1992 consisted of further groundwater characterization, test pit excavations, and aquifer testing. An area of light nonaqueous phase liquid (LNAPL) consisting mainly of JP-4 was identified at the site originating from the unlined burn pit (Metcalf & Eddy, 1992).

An LNAPL recovery system was designed and installed in 1993 by OHM Remediation Services Corporation (OHM, 1993). Parsons ES has been providing operations, maintenance, and monitoring services for the LNAPL recovery system since November 1993. In addition to the reports of investigations referenced above, data from Parsons ES activities were reviewed to formulate the conceptual model presented in Section 2.

SECTION 2

DATA REVIEW AND CONCEPTUAL MODEL DEVELOPMENT

Existing site-specific data were reviewed and used to develop a conceptual model of the groundwater flow and contaminant transport system at FPTA No. 4. This conceptual model will guide the collection of additional data which will be used to support the Bioplume II modeling effort, and to evaluate potential remediation technologies, including intrinsic remediation. Section 2.1 presents a synopsis of available site data. Section 2.2 presents the preliminary conceptual groundwater flow and solute transport model which was developed based on these data.

2.1 DATA REVIEW

The Remedial Investigation Report prepared by Metcalf & Eddy, Inc. (1992) contains recent environmental and regional data for the site. In addition, the OHM (1993) operations and maintenance manual and the monitoring data collected by Parsons ES were reviewed. Additional information was provided by Pope AFB during the site visit on March 28, 1995. Relevant data are summarized in the following sections.

2.1.1 Climate, Topography, and Surface Hydrology

The Fayetteville, NC area has a temperate climate resulting from its latitude and its close geographic proximity to the Atlantic Ocean. Spring and fall are characterized by a succession of warm and cold periods associated with storm activity. Summers and winters are characterized as humid, making the winters more penetrating and the summers more sweltering than experienced in the drier climates of the central United States (Climates of the States, 1985). The mean annual precipitation for the base is approximately 47.7 inches per year (NCSU, 1988). Mean daily temperatures range from 41.4 to 79.3 degrees Fahrenheit ($^{\circ}$ F) (NCSU, 1988).

The majority of the land area at Pope AFB exhibits little topographic variation. The southern corner of the base is the high point at approximately 270 feet (ft) above mean sea level (msl), and the lowest elevations are found along the northern boundaries of the base near the Little River. Site FPTA No. 4 is located at approximately 235 ft msl. Most of the land area at the main portion of the base has been leveled. Most significant

elevation changes within the borders of Pope AFB are the result of erosional activity and/or stream channel development.

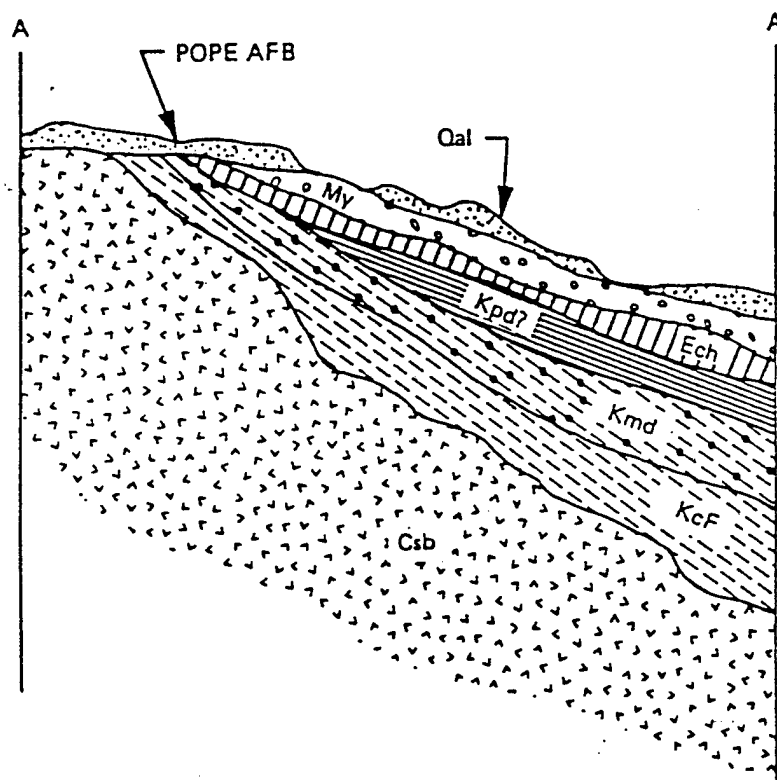
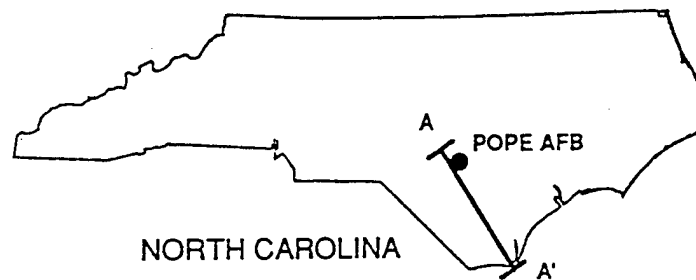
The primary surface water drainage features at Pope AFB are the Little River, which runs north of the northern border of the base, and Tank Creek, a major tributary to the Little River that runs through the southern and eastern portions of the base. Storm water is drained from the base to either Tank Creek or the Little River through a system of drainageways and subsurface piping. Many of the drainageways are in direct communication with groundwater in the surficial aquifer and act as groundwater discharge boundaries. There are also several wetland areas within the boundaries of Pope AFB into which groundwater discharges. One of these wetland areas is located immediately west of FPTA No. 4 (Figure 1.3) and is drained by Tank Creek.

2.1.2 Overview of Geology and Hydrogeology

2.1.2.1 Local Geology and Hydrogeology

Pope AFB is located in the Sandhills Subprovince of the Atlantic Coastal Plain Physiographic Province, a wide wedge-shaped belt of Cretaceous to Recent sedimentary deposits (Foster, 1950). Surface features in the Sandhills area consist mainly of rounded hills of loose to fairly well consolidated Cretaceous sands (Schipf, 1961). In addition, dendritic drainage patterns and wide, swampy flood plains typify the Sandhills Subprovince. Pope AFB is located approximately 10 miles east of the Fall Line, which marks the boundary between the Coastal Plain and the Piedmont physiographic provinces. In the area of the base, the geology consists of unconsolidated sediments unconformably overlying Cambrian bedrock of the Carolina Slate Belt (Metcalf & Eddy, 1992). The Coastal Plain sediments at Pope AFB are primarily made up of a thin veneer of Quaternary and Tertiary deposits overlying Cretaceous marine sediments (Figure 2.1).

At the base, fluvial and swamp deposits along surface water features make up the surficial deposits of Quaternary alluvium. These alluvial deposits are typically only several inches to several feet thick. Beneath the Quaternary and Tertiary sediments, the Middendorf and the Cape Fear Formations underlie Pope AFB. The Middendorf Formation is made up of fine to coarse sand with thin seams of silt and clay. At the base, the Middendorf Formation has been described as brownish-yellow to very pale brown, loose to slightly cohesive sands (Metcalf & Eddy, 1992). The Cape Fear



LEGEND

AGE	SYMBOL	FORMATION NAME
QUATERNARY	Qal	Alluvium
TERTIARY	My	Yorktown
	Ech	Castle Hayne
CRETACEOUS	Kpd	Pee Dee
	Kmd	Middendorf
	Kcf	Cape Fear
CAMBRIAN	Csb	Carolina Slate Belt

FIGURE 2.1

REGIONAL GEOLOGICAL CROSS-SECTION

Intrinsic Remediation EE/CA
FPTA No. 4
Pope AFB, NC

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Formation is described as a light gray to gray micaceous unit consisting of discontinuous lenses of varying mixtures of sand, silt, and clay that are densely-packed, stiff, and slightly to moderately plastic. A gravelly sand unit has also been noted on the northern portion of the base (Metcalf & Eddy, 1992).

The uppermost hydrogeologic unit at Pope AFB consists of a surficial unconfined aquifer within the Cretaceous Aquifer System. Groundwater flow directions within the surficial aquifer are controlled by topography on a local scale. The overall direction of flow in the surficial aquifer is generally to the north and northeast toward the Little River. Within the boundaries of Pope AFB, groundwater flows toward the local drainage features (especially Tank Creek).

The surficial aquifer is underlain by a series of interbedded sands and clays making up the regional aquifer units of the Cretaceous Aquifer System. Because the interbedded formations which make up the Cretaceous Aquifer System are discontinuous, it is difficult to identify separate and distinct aquifers within the system. In the Fayetteville area, the Cretaceous aquifer is the primary source of groundwater supplies. Beneath the Cretaceous aquifer, the crystalline bedrock aquifer forms the deepest hydrogeologic unit in the area. The bedrock aquifer, only productive in areas of high fracturing, is made up of volcanic, volcanoclastic, and granitic rock of the Carolina Slate Belt. The depth to bedrock in the vicinity of the base is on the order of 100 feet below land surface (bls).

2.1.2.2 Site Geology and Hydrogeology

Groundwater at FPTA No. 4 is found at depths ranging from approximately 13 to less than 1 ft bls. Table 2.1 provides monitor well construction data for the site. A water table contour map from a previous investigation is shown in Figure 2.2. Groundwater flow at the site is to the west, toward a wetland area that feeds into Tank Creek.

TABLE 2.1
SUMMARY OF WELL CONSTRUCTION RECORDS
INTRINSIC REMEDIATION EE/CA
FPTA NO. 4
POPE AFB, NC

Well No.	Total Depth (ft)	Screened Interval (ft. bgs)	Approximate Depth to Water (ft. bgs)
PHASE 1			
MW1-14	14	4-14	6
MW1-15	14	4-14	4
MW1-16	14	4-14	3.5
MW1-17	13.5	3.5-13.5	5
MW1-18	14	4-14	1
PHASE 2			
MW1-20	19.5	9-19	14
MW1-21	16.5	9-14	5
MW1-22	15	4.5-14.5	6
MW1-23	14.75	3.25-13.25	3.5
MW1-24	14	3.5-13.5	5

Source: Metcalf & Eddy, 1992

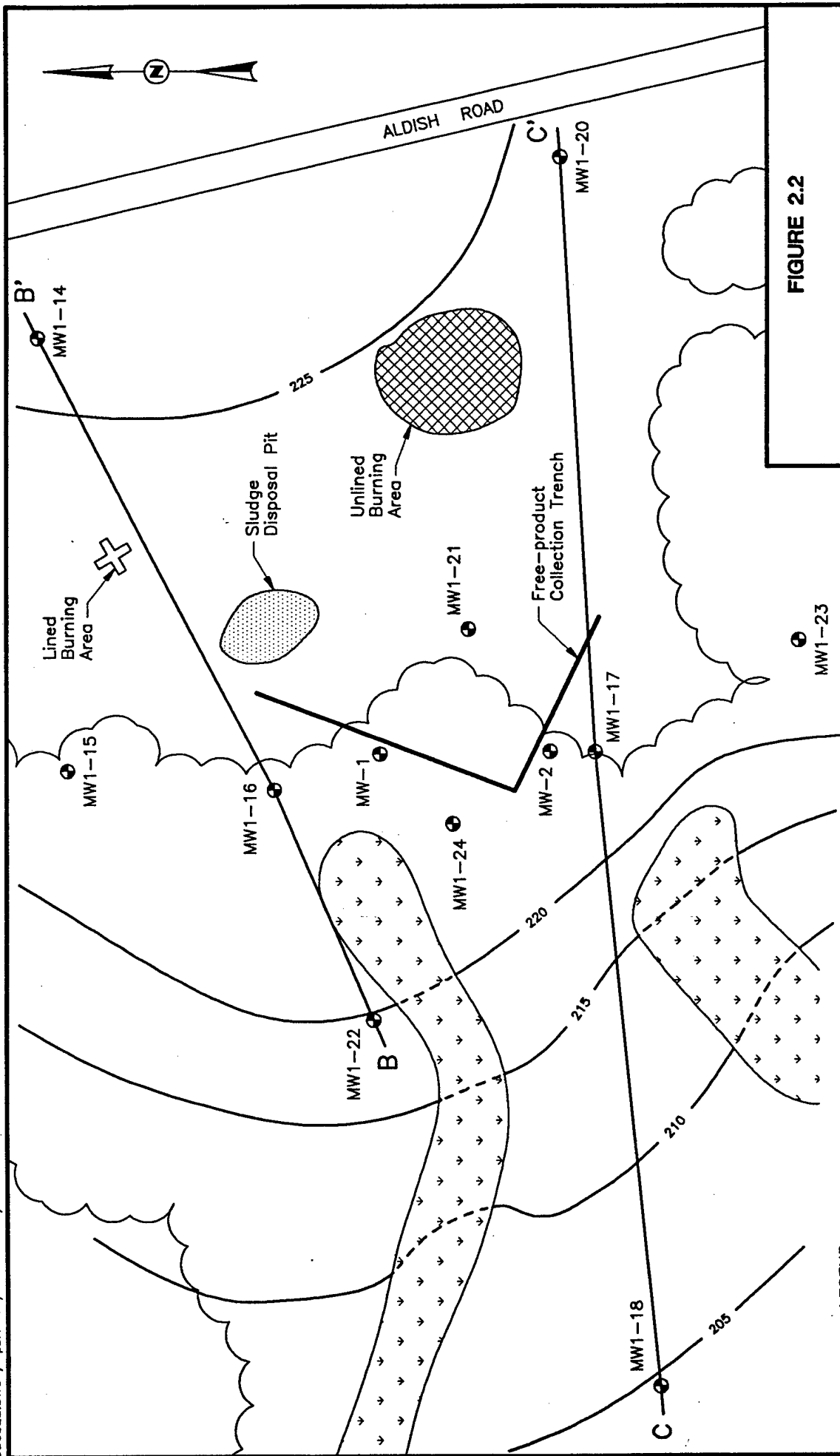


FIGURE 2.2

WATER TABLE ELEVATION MAP FEBRUARY 1992

Intrinsic Remediation EE/CA
FPTA No. 4
Pope AFB, NC



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Cary, North Carolina

LEGEND

- Monitoring well.
- 225— Water table elevation (feet above mean sea level).
- [Dashed line with arrows] Estimated areal extent of wetlands.
- B—B' Geologic cross-section location.



Source: Metcalf & Eddy, 1992.

Figures 2.3 and 2.4 show geologic cross-sections from site investigations performed at FPTA No. 4. The site stratigraphy consists of some areas of sandy topsoil and/or fill material, underlain by 20 to 30 feet of Middendorf Formation sands, which are in turn underlain by the less permeable sediments of the Cape Fear Formation. As shown in Figure 2.2, groundwater discharges into wetland areas near the site. The horizontal hydraulic conductivity of the surficial aquifer at Pope AFB has been reported to range from 8 to 37 feet per day (ft/day) based on slug testing. Based on infiltration testing, vertical hydraulic conductivity ranges from 4 to 7 ft/day (Metcalf & Eddy, 1992).

2.1.3 Soil Quality

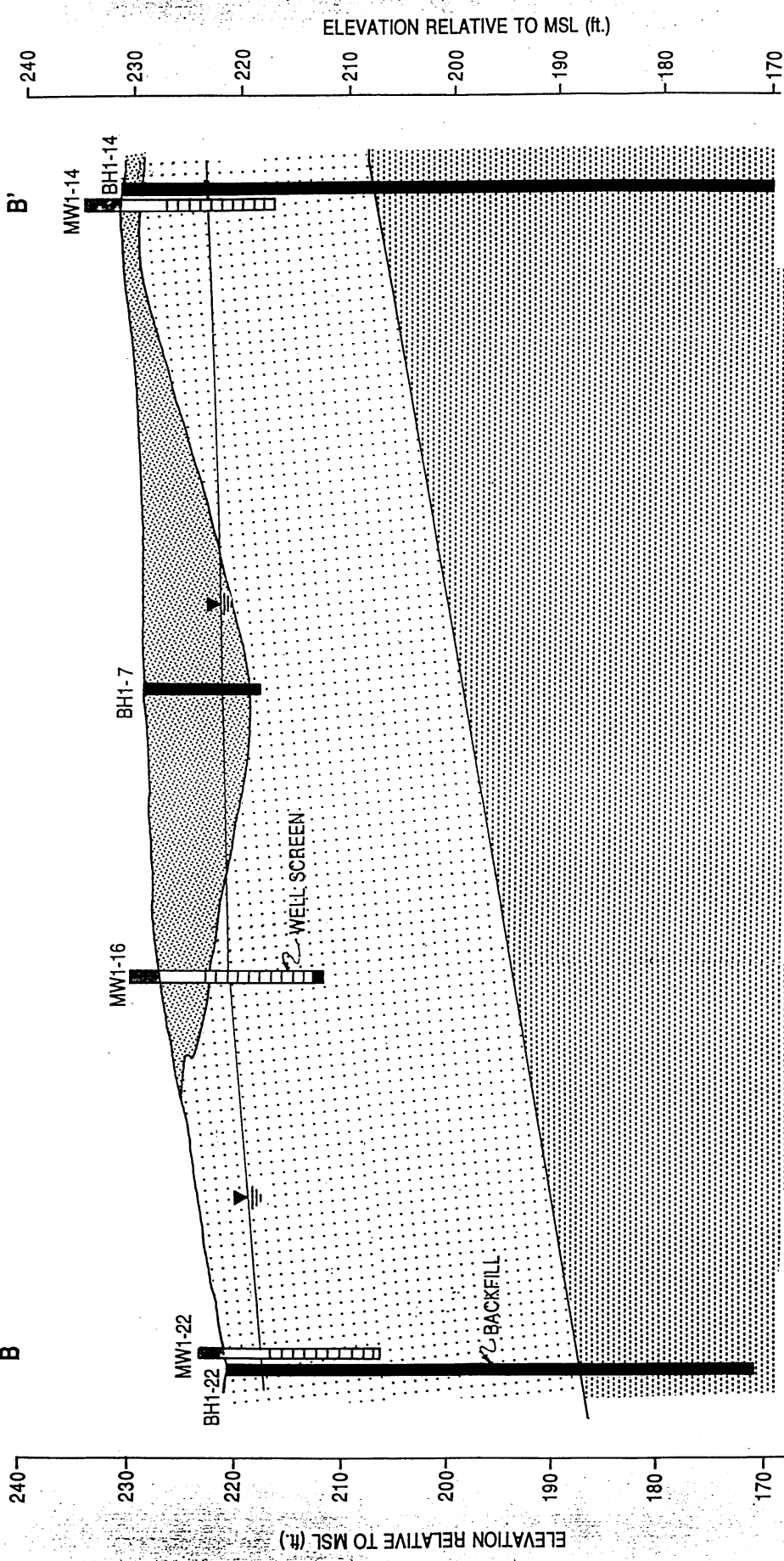
Characterization of the contaminant concentrations in site soils at FPTA No. 4 was the objective of several investigative phases at the site. Analytical results are available from 59 soil samples collected from borings and 12 soil samples collected from test pits (Metcalf & Eddy, 1992). A summary of compounds detected in soil and water samples, frequency of detections, and maximum concentrations detected is provided in Table 2.2. Appendix A contains soil sample data collected by Metcalf & Eddy (1992). Total petroleum hydrocarbons (TPH) and lead were the most frequently detected contaminants (Metcalf & Eddy, 1992). Figure 2.5 shows the general area of soil TPH contamination. Benzene, toluene, ethylbenzene, and xylenes (BTEX) were also detected in relatively high concentrations in the soil at the site.

2.1.4 Groundwater Quality and Chemistry

Groundwater analytical results are available from monitoring wells (laboratory analyses) and from in-situ groundwater screening (using a field gas chromatograph). In addition, water samples were collected from several seeps where groundwater discharges to the surface in the wetland area adjacent to the site. These samples were designated "leachate" samples by Metcalf & Eddy (1992). A summary of groundwater and "leachate" results is shown in Table 2.2. Detailed data are provided in Appendix B. The most frequently detected compounds in groundwater and leachate were BTEX, TPH, and lead. Concentrations up to 3,800 micrograms per liter ($\mu\text{g/L}$) of BTEX compounds were detected in groundwater. In addition, at several locations, relatively low concentrations of chlorinated hydrocarbons were also detected in groundwater samples.

SW
B

NE
B'



Note:
See Figure 2.2 for cross-section location.

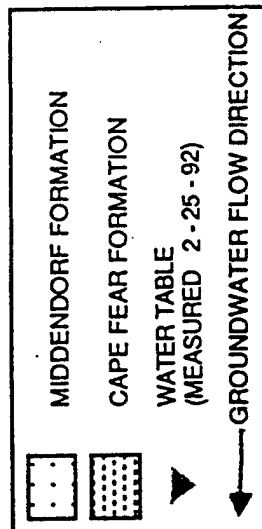
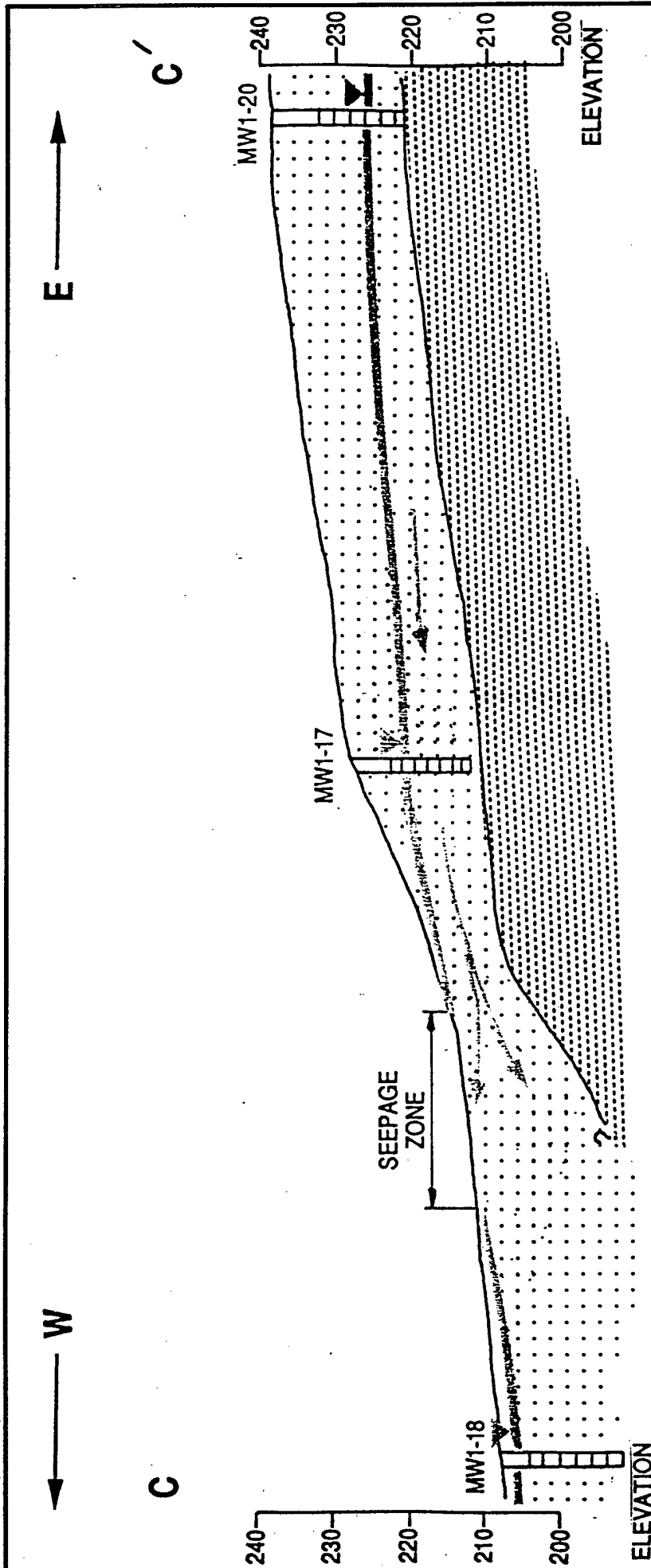
Source: Metcalf & Eddy, 1992.

FIGURE 2.3

GEOLOGIC CROSS-SECTION
B-B'

Intrinsic Remediation EE/CA
FPTA No. 4
Pope AFB, NC

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Note:
See Figure 2.2 for cross-section location.

Source: Metcalf & Eddy, 1992.

FIGURE 2.4

GEOLOGIC CROSS-SECTION C-C'

Intrinsic Remediation EE/CA
FPTA No. 4
Pope AFB, NC



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TABLE 2.2
SUMMARY OF SITE CONTAMINANTS AND CONCENTRATIONS
INTRINSIC REMEDIATION EE/CA
FPTA NO. 4
POPE AFB, NC

Contaminant	Test Pits		Soil Borings		Groundwater		Leachate Water		Sediment	
	Max ¹ mg/kg	D/A ²	Max mg/kg	D/A	Max µg/L	D/A	Max µg/L	D/A	Max mg/kg	D/A
METALS										
Chromium (total)	8.3	5/12	9.0	5/10	52.5	2/13		0/5	5.0	1/2
Lead (total)	133J ⁴	12/12	178	58/59	624	12/20	10.9	4/5	54.6J	5/5
TPHs	19500	8/12	44000	49/59	20.5	5/20	2.8	2/5	1100	1/5
VOCs										
Acetone	11J	2/12	58B	2/59		0/20		0/5	0.18	3/5
Benzene	0.026	1/12	9.9JMA	3/59	1500	11/20	69	3/5	0.054	3/5
Toluene	88.5	4/12	100J	12/59	3800	6/20		0/5		0/5
Ethylbenzene	51.5	6/12	60	14/59	575	9/20	66	2/5	0.052	2/5
Xylene	305	6/12	720J	13/59	3250	9/20	290	3/5	0.21	2/5
1,2-Dichlorobenzene	4.8	2/12	3.2J	2/59	33	4/17		0/5		0/5
1,3-Dichlorobenzene		0/12	5.9J	2/59		0/17		0/5		0/5
1,4-Dichlorobenzene	13.5	3/12		0/59	48.5	4/17		0/5		0/5
Trichloroethene		0/12		0/59	5	3/17		0/5		0/5
Tetrachloroethene		0/12	1.2J	1/59	4.75	1/17		0/5		0/5
1,2-Dichloroethene		0/12		0/59	110	3/17		0/5		0/5
Vinyl chloride		0/12		0/59	11	3/17		0/5		0/5
1,1-Dichloroethene		0/12		0/59	1.02	1/17		0/5		0/5
1,1-Dichloroethane		0/12		0/59	9.7	2/17		0/5		0/5
1,2-Dichloroethane		0/12		0/59	5.6	1/17		0/5		0/5
1,1,1-Trichloroethane		0/12		0/59	6.5	1/17		0/5		0/5
1,1,2-Trichloroethane		0/12		0/59	5.4	1/17		0/5		0/5
1,2-Dichloropropane		0/12		0/59	1.35	1/17		0/5		0/5
1,1,2,2-Tetrachloroethane		0/12	0.91J	1/59	0.56	1/17		0/5		0/5
Chloroform		0/12		0/59	4	1/17		0/5		0/5
Bromoform		0/12		0/59	0.603	1/17		0/5		0/5
Methylene Chloride	0.008	5/12	43B ⁴	1/59		0/17		0/5		0/5
2-Butanone		0/12	25J	1/59		0/17		0/5		0/5
2-Hexanone		0/12	440	11/59		0/17		0/5		0/5
4-Methyl-2-pentanone		0/12	159	12/59		0/17		0/5		0/5
Carbon Disulfide		0/12		0/59		0/17		0/5	0.018J	2/5
Trans-1,3-Dichloropropene		0/12	0.86J	1/59		0/17		0/5		0/5

Continued...

TABLE 2.2 (CONCLUDED)
SUMMARY OF SITE CONTAMINANTS AND CONCENTRATIONS
INTRINSIC REMEDIATION EE/CA
FPTA NO. 4
POPE AFB, NC

Contaminant	Test Pits		Soil Borings		Groundwater		Leachate Water		Sediment	
	Max ¹ mg/kg	D/A ²	Max mg/kg	D/A	Max µg/L	D/A	Max µg/L	D/A	Max mg/kg	D/A
SVOCs	NA ⁴	NA								
bis(2-Ethylhexyl)phthalate			1	5/49		0/7		0/5	11B	2/3
Fluorene			3.1J	5/49		0/7		0/5		0/3
Anthracene			0.76	1/49		0/7		0/5		0/3
Phenanthrene			3.1	6/49		0/7		0/5		0/3
Fluoranthene			3.8	1/49		0/7		0/5		0/3
Pyrene			2.3	1/49		0/7		0/5		0/3
Benzo(a)anthracene			1.6	1/49		0/7		0/5		0/3
Chrysene			1.8	1/49		0/7		0/5		0/3
Di-n-Octyl phthalate				0/49		0/7		0/5		0/3
Benzo(b)fluoranthene			1.2	1/49		0/7		0/5		0/3
Benzo(k)fluoranthene			0.94	1/49		0/7		0/5		0/3
Benzo(a)pyrene			1.2	1/49		0/7		0/5		0/3
Naphthalene			56	12/49	55	4/7	22	1/5		0/3
Di-n-Butylphthalate			0.38J	1/49		0/7		0/5	0.75JMA ⁶	1/3
2,4-Dimethylphenol				0/49	42	2/7		0/5		0/3
¹ Max - Maximum detected value ² D/A - Times detected/Times analyzed ³ J - Estimated value ⁴ NA - Not analyzed ⁵ B - Detection Blank ⁶ JMA - Estimated, Method Blank Approximation										

Source: Metcalf & Eddy, 1992

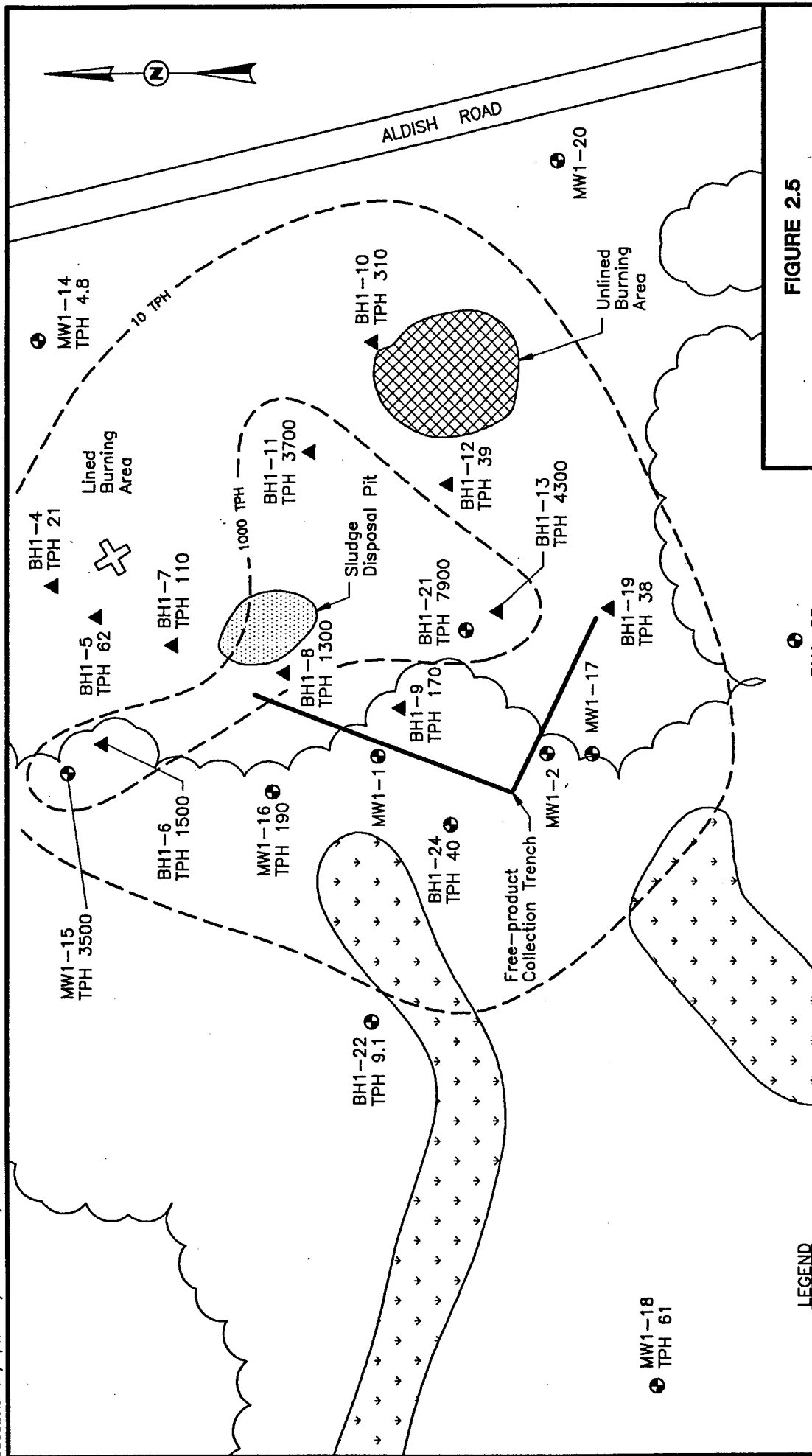


FIGURE 2.5

TOTAL PETROLEUM HYDROCARBON ISOPLETHS FOR SOIL

Intrinsic Remediation EE/CA
FPTA No. 4
Pope AFB, NC



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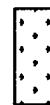
Cary, North Carolina



LEGEND

Monitoring well.

Soil boring.



Estimated areal extent of wetlands.

TPH concentration isopleths, mg/kg.

ND Not detected.

Source: Metcalf & Eddy, 1992.

In addition to dissolved BTEX compounds at the site, an LNAPL plume has been delineated at the site (Metcalf & Eddy, 1992). The migration of the LNAPL plume is controlled by a recovery trench system. The approximate extent of the LNAPL plume is shown on Figure 2.6. The recovery system skims LNAPL only and does not significantly impact the flow of groundwater. The layout of the recovery system at the site is also shown on Figure 2.6.

2.2 DEVELOPMENT OF CONCEPTUAL MODEL

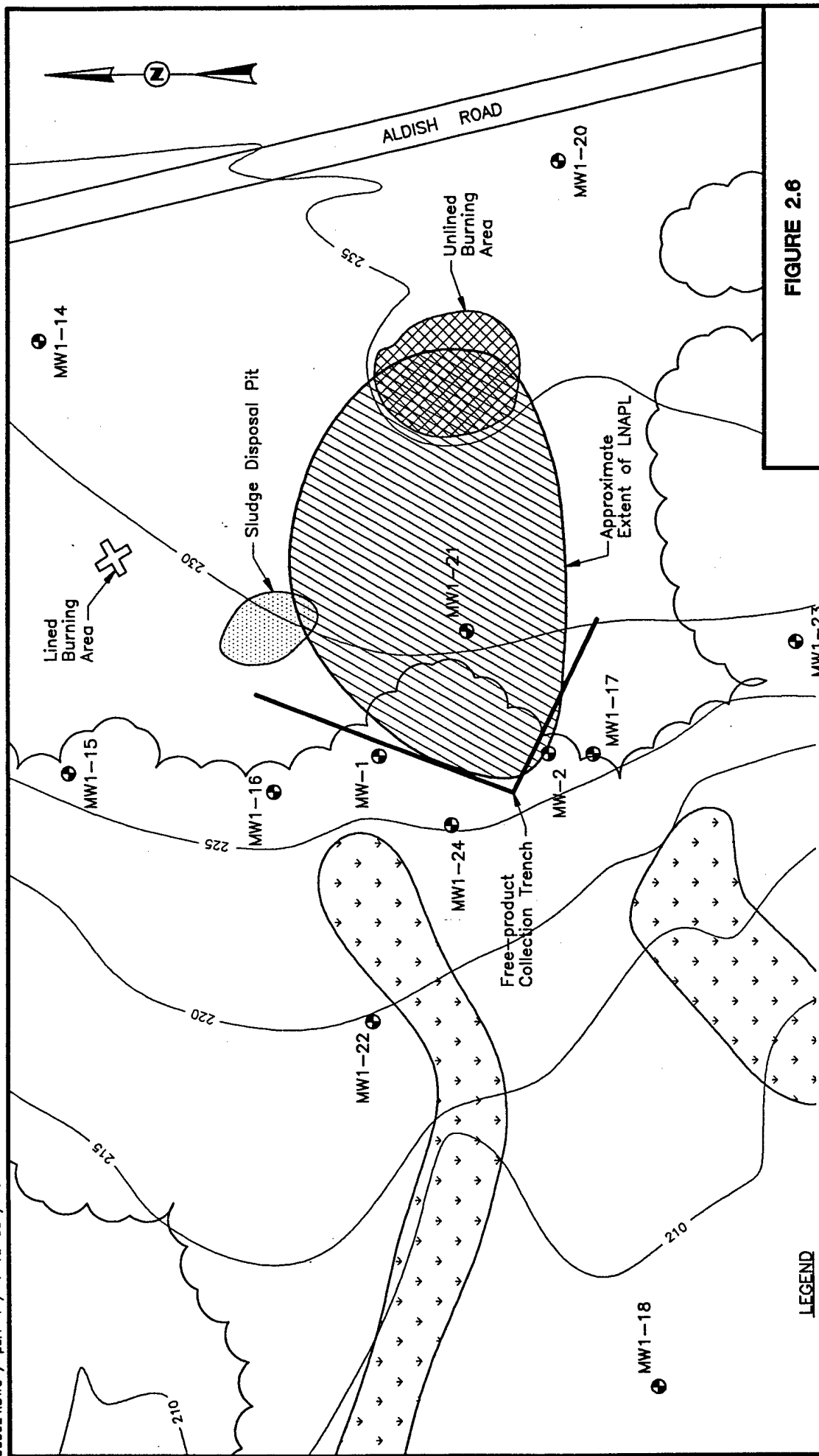
The FPTA No. 4 site conceptual model is a three-dimensional representation of the hydrogeologic system based on available geological, hydrological, climatological, and geochemical data. The purpose of the conceptual model is to integrate available data so that a coherent representation of the groundwater flow and contaminant transport system can be developed. The conceptual model will be used to aid in locating additional data collection points and to help develop the Bioplume II model.

Successful conceptual model development involves:

- Definition of the problem to be solved;
- Model selection;
- Designing the conceptual model;
- Integrating available data, including:
 - Local geologic and topographic data,
 - Hydraulic data,
 - Site stratigraphy,
 - Contaminant concentration and distribution data; and
- Determining additional data requirements.

2.2.1 Conceptual Model Design Components

Site hydrogeologic data will be developed in detail during the field investigations. The general hydrogeologic sections (Figures 2.3 and 2.4) show, in limited detail, the



LEGEND

- Monitoring well.
- 225— Topographic contour (feet above mean sea level).
- [Dotted pattern] Estimated areal extent of wetlands.
- [Hatched pattern] Approximate extent of LNAPL.
- LNAPL Light non-aqueous phase liquid hydrocarbons.



FIGURE 2.6

APPROXIMATE EXTENT OF LNAPL

Intrinsic Remediation EE/CA
FPTA No. 4
Pope AFB, NC



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Source: Metcalf & Eddy, 1992.

relationships between hydrostratigraphic units (i.e., transmissive units and aquitards). Detailed data on the nature and spatial extent of contamination will be developed. The direction or directions of groundwater flow and contaminant transport will be fully investigated.

Because free product is present at the site, it may be necessary to use the fuel/water partitioning model of Bruce *et al.* (1991) to provide a conservative source term to model the partitioning of BTEX compounds from the free-product phase into the groundwater. In order to use this model, samples of free product must be collected and analyzed for mass fraction of BTEX compounds.

Based on available data, Parsons ES expects to model the site as an unconfined fine-to coarse-grained sandy aquifer. This conceptual model will be modified as necessary as additional site hydrogeologic data become available.

2.2.2 Potential Pathways and Receptors

Potential preferential contaminant migration pathways such as groundwater surface discharge points and subsurface utility corridors (artificial conduits) will be identified during the field work phase of this project. Such information can be obtained from Pope AFB maps which delineate areas that may facilitate rapid subsurface transport and/or surface discharge. Pathways to potential receptors may include discharge of contaminated groundwater into downgradient surface water bodies (e.g., drainageways, wetlands, Tank Creek, and the Little River), and migration of the contaminant plume toward downgradient potable and nonpotable water wells.

Potential human and/or ecological receptors of BTEX contamination in groundwater will be identified. No designated ecologically sensitive habitat has been identified at the site or within the property encompassed by Pope AFB, but are located in close proximity (Metcalf & Eddy, 1992). Three endangered species have been identified in the area; the Red-Cockaded Woodpecker, Pickering's Dawnflower, and the Spring-Flowering Goldenrod (Metcalf & Eddy, 1992). No groundwater wells are used for potable water supply at Pope AFB. Groundwater from the bedrock and overlying sedimentary aquifers is used for domestic, industrial, and public water supply in Spring Lake and Manchester (Metcalf & Eddy, 1992). The closest well for potable use was found to be approximately 1/2 miles to the north of the base, and immediately south of the Little River (Metcalf & Eddy, 1992). Because the groundwater at the site is

hydrogeologically connected to the wetland (and minor tributaries to the Little River from the wetland which flow through the base), it may be necessary to survey the area outside the immediate vicinity of the site to identify any other possible receptors.

SECTION 3

COLLECTION OF ADDITIONAL DATA

To complete the EE/CA and to evaluate whether natural attenuation of site-related contaminants is occurring at the former FPTA No. 4 site, additional site-specific hydrogeologic data will be collected. The physical and chemical hydrogeologic parameters listed below will be determined during the field work phase of the EE/CA.

Physical hydrogeologic characteristics include:

- Depth from measurement datum to the groundwater surface in monitoring wells and monitoring points;
- Depth from measurement datum to the base of the shallow saturated zone (where feasible);
- Locations of potential groundwater recharge and discharge areas;
- Locations of downgradient wells and their uses;
- Hydraulic conductivity through slug tests, as required;
- Estimate of dispersivity, where possible;
- Stratigraphic analysis of subsurface media;
- Groundwater temperature; and
- Determination of extent and thickness of free- and residual-phase product.

Chemical hydrogeologic characteristics include:

- Dissolved oxygen (DO) concentration;
- Specific conductance;
- pH;
- Reduction/oxidation (redox) potential;

- Chemical analysis of free product to determine mass fraction of BTEX; and
- Chemical analysis of groundwater and soil for the parameters listed in Table 3.1.

These data will be collected and analyzed by a combination of Parsons ES field scientists and scientists from USEPA RSKERL.

Several investigations have been performed at the former FPTA No. 4 site. The data developed through these investigations will be used as needed for the overall evaluation of the site in the EE/CA. In addition, the AFCEE Geoprobe® truck will be used for the installation of additional groundwater monitoring points and for soil and groundwater sampling at the site in support of the EE/CA. This work is to take place starting the first week of May 1995. Groundwater and free product samples will also be collected, as needed, to support the intrinsic remediation option. The following sections describe the procedures that will be followed when collecting additional site-specific data. Geoprobe® soil sampling procedures are described in Section 3.1. Procedures to be used for the installation of permanent monitoring points and temporary sampling points are described in Section 3.2. Procedures to be used for groundwater sampling are described in Section 3.3. Aquifer parameters (i.e., hydraulic conductivity, if deemed necessary) will be measured using the procedures described in Section 3.4.

3.1 SOIL SAMPLING

The following sections describe sample collection techniques, sampling locations, equipment decontamination procedures, site restoration, and management of investigation-derived waste materials.

3.1.1 Sample Collection Using the Geoprobe® System

The Geoprobe® system is a hydraulically powered percussion/probing machine used to advance sampling tools through unconsolidated soils. This system provides for the rapid collection of soil, soil gas, and groundwater samples at shallow depths while minimizing the generation of investigation-derived waste materials. Figure 3.1 is a diagram of the Geoprobe® system. The following sections describe soil sample collection methods and decontamination methods for use with the Geoprobe® system.

TABLE 3.1
ANALYTICAL PROTOCOL FOR
GROUNDWATER AND SOIL SAMPLES
INTRINSIC REMEDIATION EE/CA

FPTA NO. 4
POPE AFB, NC

MATRIX	METHOD	FIELD (F) OR ANALYTICAL LABORATORY (L)
WATER		
Total Iron	Colorimetric, HACH Method 8008 (or similar)	F
Ferrous Iron (Fe^{+2})	Colorimetric, HACH Method 8146 (or similar)	F
Ferric Iron (Fe^{+3})	Difference between total and ferrous iron	F
Manganese	Colorimetric, HACH Method 8034 (or similar)	F
Sulfide	Colorimetric, HACH Method 8131 (or similar)	F
Sulfate	Colorimetric, HACH Method 8051 (or similar)	F
Nitrate	Titrimetric, HACH Method 8039 (or similar)	F
Nitrite	Titrimetric, HACH Method 8507 (or similar)	F
Redox Potential	A2580B, direct reading meter	F
Oxygen	Direct reading meter	F
pH	E150.1/SW9040, direct reading meter	F
Conductivity	E120.1/SW9050, direct reading meter	F
Temperature	E170.1	F
Alkalinity (Carbonate [CO_3^{-2}] and Bicarbonate [HCO_3^{-1}])	Titrimetric, HACH Method 8221 (or similar)	F
Carbon Dioxide	Titrimetric, HACH Method 1436-01	F
Nitrate + Nitrite	EPA Method 353.1	L
Chloride	Waters Capillary Electrophoresis Method N-601	L
Sulfate	Waters Capillary Electrophoresis Method N-601	L
Methane, Ethane, Ethene	RSKSOP-147	L
Dissolved Organic Carbon	RSKSOP-102	L
VOCs, Chlorinated Included	RSKSOP-148	L
Fuel Carbon	RSKSOP-148	L
SOIL		
Total Organic Carbon	RSKSOP-102 & RSKSOP-120	L
Moisture	ASTM D-2216	L
Aromatic Hydrocarbons	RSKSOP-124, modified	L
VOCs	RSKSOP-148	L
Total Hydrocarbons	RSKSOP-174	L
FREE PRODUCT		
BTEX Mass Fraction	GC/MS, Direct Injection	L

Note: RSKSOP = RSKERL Standard Operating Procedure.

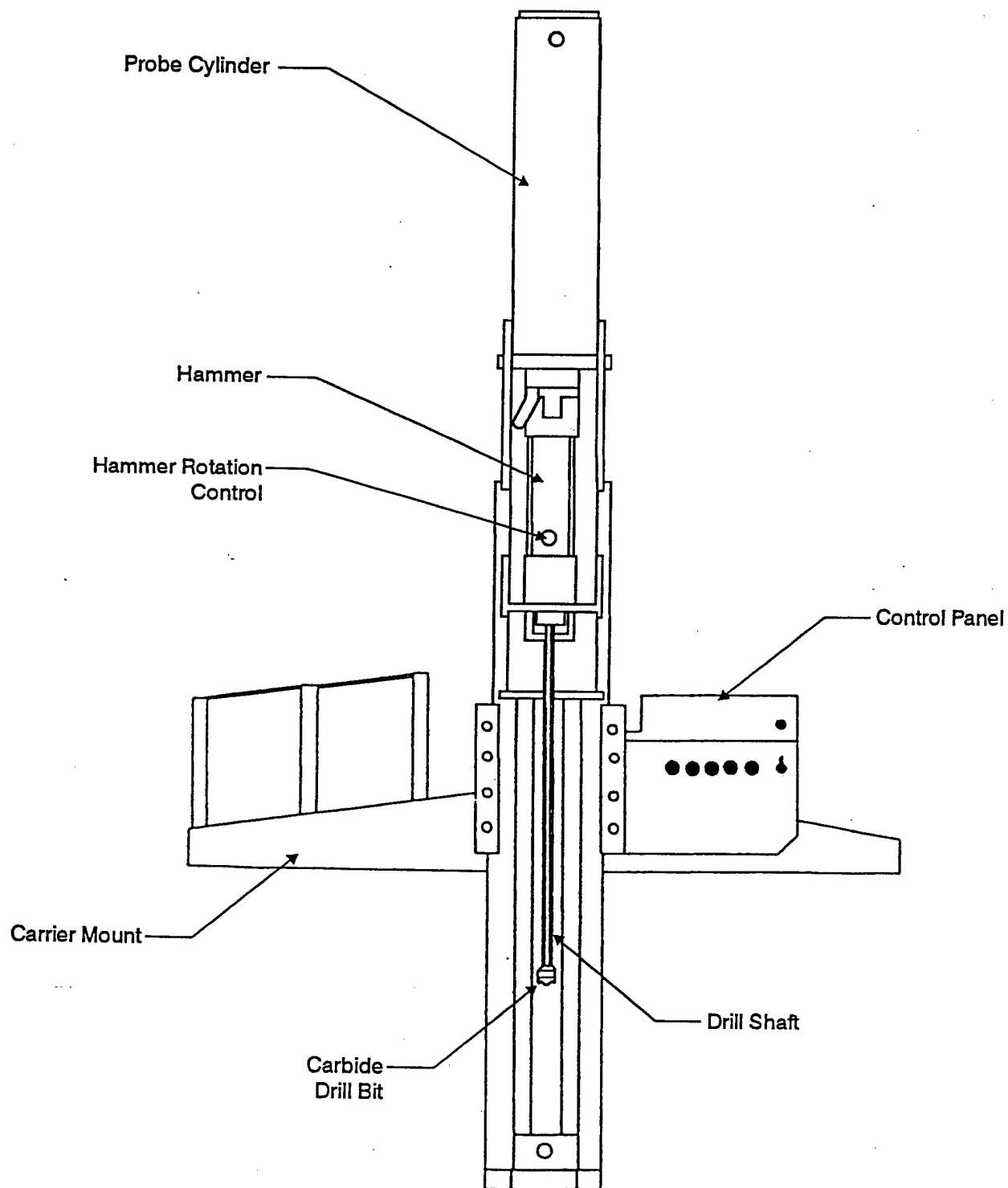


FIGURE 3.1

CROSS SECTION
OF GEOPROBE

Intrinsic Remediation EE/CA
FPTA No. 4
Pope AFB, NC



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Soil samples will be collected using a probe-drive sampler. The probe-drive sampler serves as both the driving point and the sample collection device and is attached to the leading end of the probe rods. To collect a soil sample, the sampler is pushed or driven to the desired sampling depth, the drive point is retracted, which opens the sampling barrel, and the sampler is subsequently pushed into the undisturbed soils. The soil cores are retained within brass, stainless steel, or clear acetate liners inside the sampling barrel. The probe rods are then retracted, bringing the sampling device to the surface. The soil sample can then be extruded from the liners for logging or the liners can be capped and undisturbed samples submitted to the analytical laboratory for testing.

If the probe-drive sampling techniques described above are inappropriate, inadequate, or unable to efficiently provide sufficient soil samples for the characterization of the site, continuous soil samples will be obtained from conventional sore boreholes using a hand auger or similar method judged acceptable by the Parsons ES field scientist. Procedures will be modified, if necessary, to ensure good sample recovery.

The Parsons ES field scientist will be responsible for observing all field investigation activities, maintaining a detailed descriptive log of all subsurface materials recovered during soil coring, photographing representative samples, and properly labeling and storing samples. An example of the proposed geologic boring log form is presented in Figure 3.2. The descriptive log will contain:

- Sample interval (top and bottom depth);
- Sample recovery;
- Presence or absence of contamination;
- Lithologic description, including relative density, color, major textural constituents, minor constituents, porosity, relative moisture content, plasticity of fines, cohesiveness, grain size, structure or stratification, relative permeability, and any other significant observations; and
- Depths of lithologic contacts and/or significant textural changes measured and recorded to the nearest 0.1 foot.

GEOLOGIC BORING LOG

Sheet 1 of 1

BORING NO.: _____ CONTRACTOR: _____ DATE SPUD: _____
 CLIENT: AFCEE RIG TYPE: _____ DATE CMPL.: _____
 JOB NO.: 722450.17 DRLG METHOD: _____ ELEVATION: _____
 LOCATION: POPE AFB BORING DIA.: _____ TEMP: _____
 GEOLOGIST: _____ DRLG FLUID: _____ WEATHER: _____
 COMMENTS: _____

Elev (ft)	Depth (ft)	Pro- file	US CS	Geologic Description	Sample		Penet Res	PID(ppm)	WKSPC PID(ppm)	TOTAL BTX(ppm)	TPH (ppm)
					No.	Depth (ft)					
	1										
	5										
	10										
	15										
	20										
	25										
	30										

NOTES

bgs - Below Ground Surface
 GS - Ground Surface
 TOC - Top of Casing
 NS - Not Sampled
 SAA - Same As Above

SAMPLE TYPE

D - DRIVE
 C - CORE
 G - GRAB



Water level drilled

FIGURE 3.2

GEOLOGIC BORING LOG

Intrinsic Remediation EE/CA
 FPTA No. 4
 Pope AFB, NC



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Cary, North Carolina

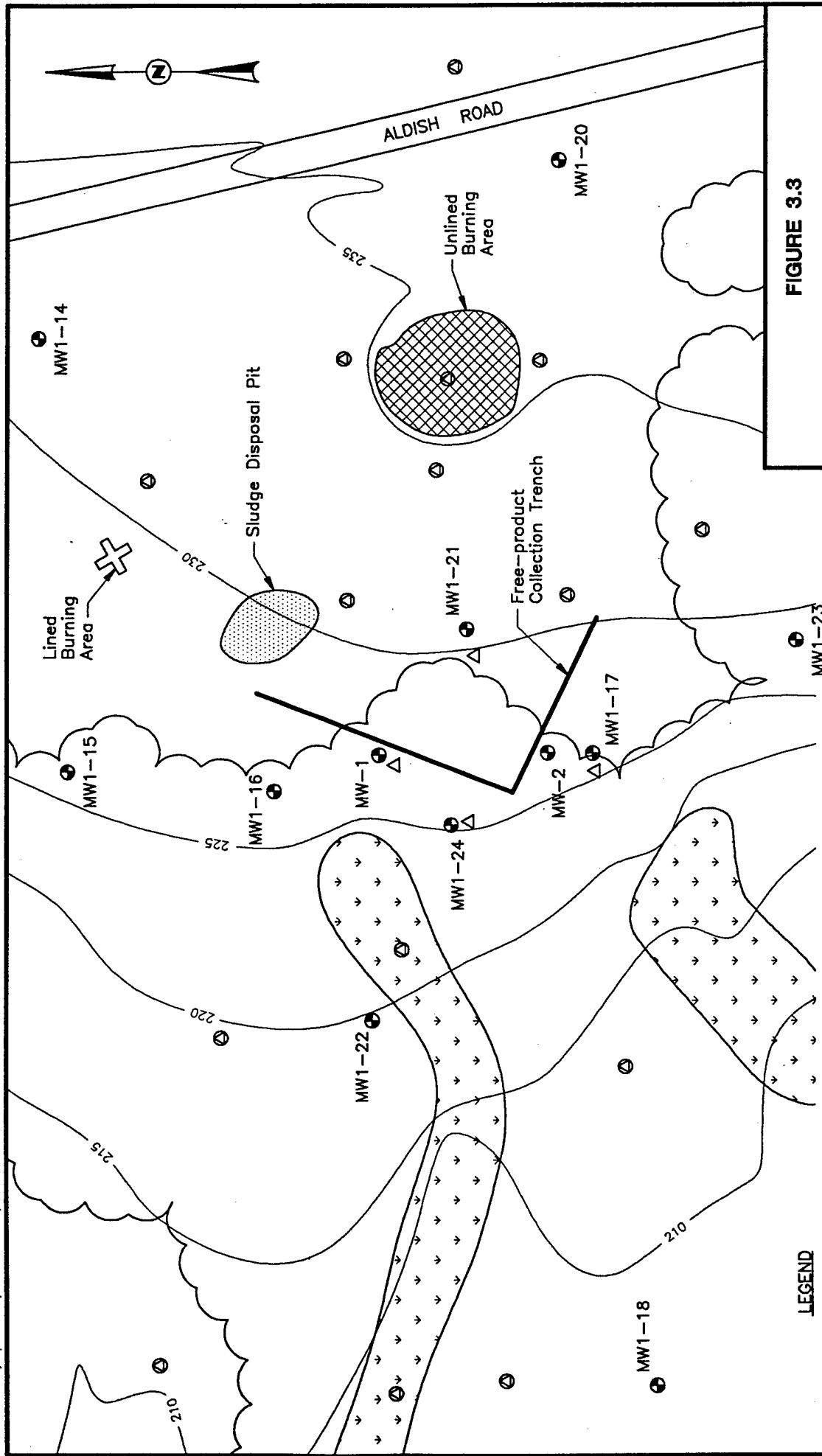
Base personnel will be responsible for identifying the location of all utility lines, USTs, fuel lines, or any other underground infrastructure prior to any sampling activities. All necessary digging permits will be obtained by Base personnel prior to mobilizing to the field. Base personnel will also be responsible for acquiring drilling and monitoring point installation permits for the proposed locations. Also, a room with a desk and table should be provided near the FPTA No. 4 site, for RSKERL's mobile laboratory equipment. Parsons ES will be responsible for providing trained operators for the Geoprobe®.

3.1.2 Soil Sample Locations and Required Analyses

This section identifies the proposed locations for soil sampling at the FPTA No. 4 site at Pope AFB. Table 3.1 presents an analytical protocol for groundwater and soil samples, and Appendix C contains detailed information on the analyses and methods used during this sampling effort.

Soil samples will be collected at selected Geoprobe® and monitoring point installation locations. Figure 3.3 identifies the proposed soil sampling and monitoring point installation locations at the FPTA No. 4 site. At least one soil sample will be collected from each hole punched, at the depth of maximum BTEX contamination as determined by soil headspace screening. In selected holes, one additional sample will be taken at the water table. Additional samples and sampling intervals will be collected at the discretion of the Parsons ES scientist. A total of 20 soil samples will be collected for laboratory analysis.

A portion of the sample will be sent to the laboratory for analytical analysis while another portion of the sample will be utilized to determine soil headspace. Each laboratory soil sample will be placed in an analyte-appropriate sample container and hand-delivered to the USEPA field personnel for analysis of total hydrocarbons, aromatic hydrocarbons, and moisture content using the procedures presented in Table 3.1. In addition, four samples will be analyzed for total organic carbon (TOC) from uncontaminated locations upgradient of the contaminant source. Each headspace screening sample will be placed in a sealed plastic bag or mason jar and allowed to equilibrate with the headspace for at least 5 minutes. Soil headspace will then be determined using an organic vapor meter (OVM), and the results will be recorded in the field records by the Parsons ES field scientist.



LEGEND

- Monitoring well.
- 225— Topographic contour (feet above mean sea level).
- [Pattern] Estimated areal extent of wetlands.
- △ Proposed soil sampling location.
- ⊗ Proposed monitoring point and soil sampling location.



FIGURE 3.3

**PROPOSED
SAMPLING LOCATIONS**

Intrinsic Remediation EE/CA
FPTA No. 4
Pope AFB, NC



**PARSONS
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Cary, North Carolina

3.1.3 Datum Survey

The horizontal location of all soil sampling locations relative to established Pope AFB coordinates will be measured by a licensed surveyor. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface will also be measured to the nearest 0.1 foot relative to USGS msl data. Top-of-casing elevation for any groundwater monitoring points will be measured to the nearest 0.01 foot.

3.1.4 Site Restoration

After sampling is complete, each sampling location will be restored as closely to its original condition as possible. Holes created by the Geoprobe® in sandy soils similar to those found at the Pope AFB tend to cave in soon after extraction of the drive sampler. However, any test holes remaining open after extraction of the penetrometer rod will be sealed with bentonite chips, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the groundwater. Soil sampling using the Geoprobe® creates low volumes of soil waste. Soil not used for sampling will be placed in 55-gallon drums provided by the Base and disposed of by Base personnel. Alternate methods of soil waste disposal will be considered by the Parsons ES field scientist as recommended by Base personnel.

3.1.5 Equipment Decontamination Procedures

Prior to arriving at the site, and between each sampling location, probe rods, tips, sleeves, pushrods, samplers, tools, and other downhole equipment will be decontaminated using a high-pressure, steam/hot water wash. Only potable water will be used for decontamination. All rinseate will be collected in 55-gallon drums provided by the Base and later transported to and disposed of by Base personnel.

Between each soil sample, the sampling barrel will be disassembled and decontaminated with Alconox® and potable water. The barrel will then be rinsed with deionized water and reassembled with new liners. Between uses, the sampling barrel will be wrapped in clean plastic or foil to prevent contamination.

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before each use. This includes the sample hand auger, shovel, drive sampler, drive sample sleeves, and other equipment or portions thereof that will

contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Wash with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;
- Rinse with reagent-grade isopropyl alcohol;
- Rinse with distilled or deionized water; and
- Air dry the equipment prior to use.

Any deviations from these procedures will be documented in the field scientist's field notebook.

If precleaned disposable sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory. The type of container provided and the method of container decontamination will be documented in the laboratory's permanent record of the sampling event.

Potable water to be used during equipment cleaning, decontamination, or grouting will be obtained from one of the Base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities. Precautions will be taken to minimize any impact to the surrounding area that might result from decontamination operations.

3.1.6 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

As required, field analytical equipment will be calibrated according to the manufacturers' specifications prior to field use. This applies to equipment used for soil

headspace screening and for onsite measurements of oxygen, temperature, conductivity, and pH.

3.2 MONITORING POINT INSTALLATION

To provide information regarding contaminant distribution and concentrations and groundwater elevations at the site, monitoring points will be installed. While the North Carolina Department of Environment, Health, and Natural Resources requires that permanent monitoring wells follow specific construction guidelines, it is possible to use wells constructed in the manner of monitoring points. Monitoring points (as outlined in Section 3.2.2) will be installed in selected locations and developed as described in Sections 3.2.4 and 3.2.5. Sampling of these monitoring points will follow procedures outlined in Section 3.3.

3.2.1 Monitoring Point Locations and Completion Intervals

Data collected during the preliminary site screening investigation were reviewed to determine the proposed locations for monitoring points. In several locations multi-depth monitoring points will be installed to assess the vertical delineation of groundwater contaminants. Shallow monitoring points will be placed so that the screened intervals straddle the water table. Deep monitoring points will be placed at least 5 feet below the bottom of the shallow monitoring point screen. The locations of proposed monitoring points and the completion intervals presented below are tentative and may be adjusted at the discretion of the Parsons ES field scientist. If required, permanent monitoring points will be installed and used for long-term monitoring to track migration of dissolved BTEX and/or mobile LNAPL from the FPTA No. 4 site. Temporary monitoring points may be interspersed throughout the suspected area of contamination to further describe the horizontal and vertical distribution of hydrocarbons in support of the natural attenuation remedial option. A more detailed description of the locations and completion intervals is presented in the following sections.

3.2.1.1 Permanent Monitoring Points

Six to eight permanent multi-depth monitoring points may be installed to further characterize and monitor groundwater quality at the site. Proposed locations for these points were determined from a review of data compiled from the preliminary site

screening investigation. Final monitoring point locations will be based on the initial results of the proposed field work.

3.2.1.2 Temporary Monitoring Points

In addition to the permanent monitoring points to be installed at the FPTA No. 4 site, up to seven temporary monitoring points may be installed to fully delineate the extent of hydrocarbon contamination. Possible locations of groundwater sampling points are indicated on Figure 3.3. These locations will be selected to provide geochemical and hydrogeologic data necessary for successful implementation of the Bioplume II model. For some locations, two screened depths, with 1 meter of screen each, will allow vertical delineation of the dissolved groundwater plume.

3.2.2 Monitoring Point Installation Procedures

3.2.2.1 Pre-Placement Activities

All necessary digging, coring, drilling, and groundwater monitoring point installation permits will be obtained prior to mobilizing to the field. In addition, all utility lines will be located, and proposed drilling locations will be cleared prior to any intrusive activities. Responsibilities for these permits and clearances are discussed in Section 3.1.1

Water to be used in monitoring point installation and equipment cleaning will be obtained from one of the base water supplies. Water use approval will be verified by contacting the appropriate facility personnel. The field scientist will make the final determination as to the suitability of site water for these activities.

3.2.2.2 Monitoring Point Materials Decontamination Procedures

Monitoring point installation and completion materials will be inspected by the field scientist and determined to be clean and acceptable prior to use. If not factory sealed, the well points, tubing, casing, screen, and casing plugs and caps will be cleaned with a high-pressure, steam/hot water cleaner using approved water prior to use. Materials that cannot be cleaned to the satisfaction of the field hydrogeologist will not be used.

3.2.2.3 Installation and Materials

This section describes the procedures to be used for installation of monitoring points. Monitoring points will be installed using either 0.375-inch Teflon® tubing connected to a 0.5-inch diameter stainless steel screen or a 0.5-inch inside diameter (ID)/0.75-inch outside diameter (OD) PVC screen and casing.

3.2.2.3.1 Deep Monitoring Points

The deep monitoring points will be installed in boreholes punched using the Geoprobe® system. The deep monitoring points will be constructed of a sacrificial drive point attached to a length of 0.5-inch diameter stainless steel mesh that functions as the well screen, which is connected to 0.375-inch Teflon® tubing.

To install the deep monitoring points, the borehole is punched and sampled to several feet above a target depth for the monitoring point. The probe rods are withdrawn from the borehole, and the soil sampler is replaced with the well point assembly. An appropriate length of Teflon® tubing is threaded through the probe rods and attached to the well point. The assembly is lowered into the borehole and then driven down to the target depth and sampling zone. The probe rods are removed, leaving the sacrificial tip, screen assembly and tubing behind. The saturated soil formation is likely to cave in around the screen assembly; where this does not occur, silica sand will be emplaced to create a sand pack around the well point. The borehole annular space around the tubing above the sand pack will be filled with granular bentonite or grout to form a seal to the ground surface.

3.2.2.3.2 Shallow Monitoring Points

If subsurface conditions permit, shallow monitoring points will be constructed of 0.75-inch OD/0.5-inch ID PVC casing and well screen to provide additional water level information. Approximately 1 meter of factory-slotted screen will be installed for each shallow monitoring point. Effective installation of the shallow monitoring points requires that the boreholes remain open upon completion of drilling. Shallow 0.5-inch ID PVC monitoring points will be installed by punching and sampling a borehole with the Geoprobe®. Upon removing the rods, the borehole depth will be measured to determine if the hole is staying open. If the borehole remains open, the 0.5-inch ID PVC casing and screen will be placed at the appropriate depths. The annular space around the screen will be filled with sand filter pack, and the annulus around the casing

will be filled with grout or bentonite. Monitoring point construction details will be noted on a Monitoring Point Installation Record form (Figure 3.4). This information will become part of the permanent field record for the site.

Temporary monitoring point screens will be constructed of flush-threaded, Schedule 40 PVC with an ID of 0.5 inch. The screens will be factory slotted with 0.01-inch openings. Monitoring point screens will be placed to sample and provide water level information at or near the water table. Blank monitoring point casing will be constructed of Schedule 40 PVC with an ID of 0.5-inch. All monitoring point casing sections will be flush-threaded; joints will not be glued. The casing at each monitoring point will be fitted with a bottom cap and a top cap constructed of PVC. Previously installed monitoring wells will be utilized to determine LNAPL thicknesses.

If subsurface conditions do not permit the boreholes to stay open (i.e. the formation collapses in the hole), shallow 0.5 inch-ID PVC monitoring points may be installed using the Geoprobe®. If the installation of 0.5-inch PVC monitoring points is not possible or is impractical using the Geoprobe®, monitoring points constructed of 0.375 inch Teflon® described in Section 3.2.2.3.1 will be utilized. Sufficient water level information can be obtained through the use of monitoring wells which have already been installed at the site. The decision to install 0.5-inch ID PVC monitoring points will be made in the field once the open-hole stability of subsurface soils and Geoprobe® equipment can be evaluated.

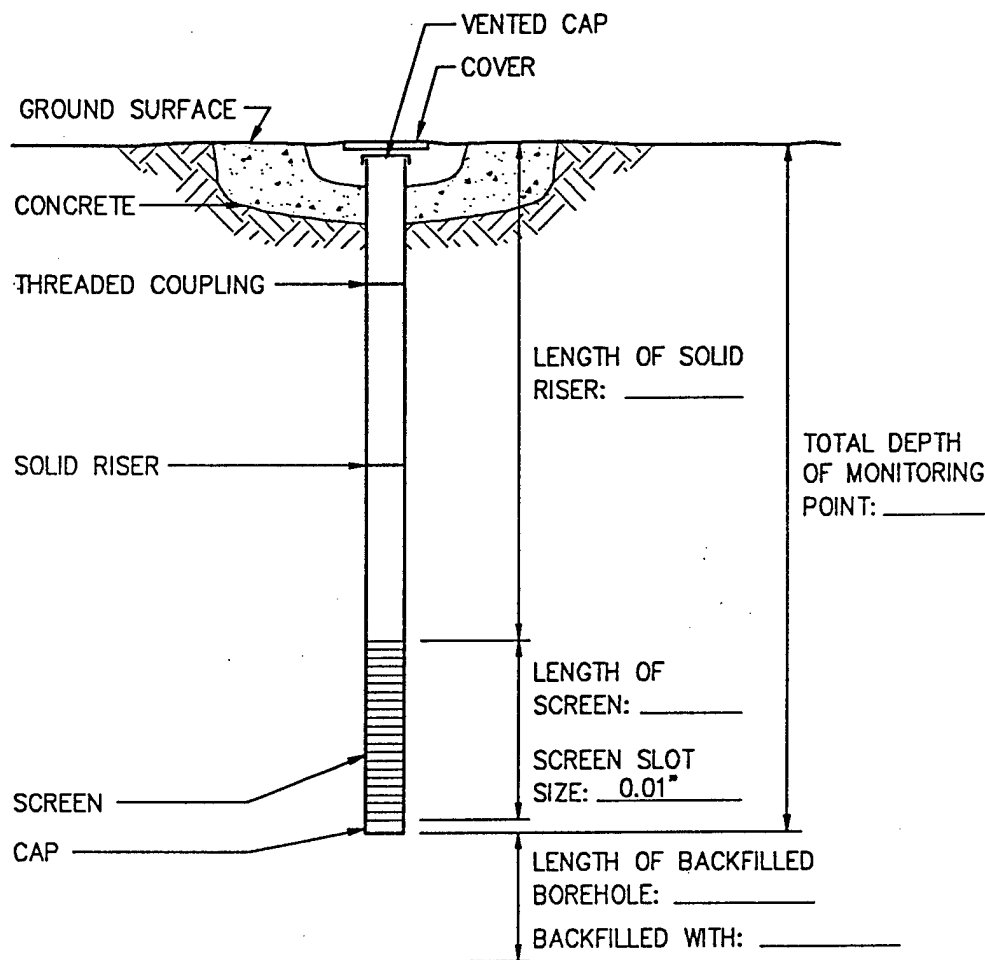
The Parsons ES field scientist will verify and record the total depth of the monitoring point, the lengths of all casing sections, and the depth to the top of all monitoring point completion materials. All lengths and depths will be measured to the nearest 0.1 foot.

3.2.2.4 Monitoring Point Completion

A number of the monitoring points will be completed abovegrade, and steel protective casing will be used to protect the well points from tampering and damage. Where pavement is present, an at-grade cover will be cemented in place using concrete blended into the existing pavement. Where pavement is not present, the protective cover will be raised slightly above the ground surface with a 1-foot square concrete pad that will slope gently away from the cover to facilitate runoff during precipitation

MONITORING POINT INSTALLATION RECORD

JOB NAME POPE AIR FORCE BASE MONITORING POINT NUMBER _____
 JOB NUMBER 722450.17 INSTALLATION DATE _____ LOCATION _____
 DATUM ELEVATION _____ GROUND SURFACE ELEVATION _____
 DATUM FOR WATER LEVEL MEASUREMENT _____
 SCREEN DIAMETER & MATERIAL _____ SLOT SIZE _____
 RISER DIAMETER & MATERIAL _____ BOREHOLE DIAMETER _____
 CONE PENETROMETER CONTRACTOR _____ ES REPRESENTATIVE _____



(NOT TO SCALE)

STABILIZED WATER LEVEL _____ FEET
 BELOW DATUM.
 TOTAL MONITORING POINT DEPTH _____ FEET
 BELOW DATUM.
 GROUND SURFACE _____ FEET

FIGURE 3.4

MONITORING POINT INSTALLATION RECORD

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events. The number of permanent monitoring points will be determined by the Parsons ES field scientist.

3.2.2.5 Monitoring Point Abandonment and Site Restoration

After monitoring point installation and sampling is complete, the site will be restored as closely as possible to its original condition. Clean and contaminated development waters and sampling purge waters will be stored in 55-gallon drums provided by the Base for later disposal by the Base.

Those monitoring points not completed with an external casing will be abandoned. The PVC casing and screen or Teflon[®] tubing will be extracted as far as possible and discarded. While holes created by the Geoprobe[®] in sandy soils similar to those found at the Base tend to cave in soon after extraction of the drive rod, any test holes remaining open after extraction of the casing will be sealed with bentonite chips, pellets, or grout to eliminate any creation or enhancement of contaminant migration pathways to the groundwater.

3.2.3 Monitoring Point Development and Records

The monitoring points will be developed prior to sampling to remove fine sediments from the portion of the formation adjacent to the well point screen. Development will be accomplished using a peristaltic pump provided by USEPA RSKERL or Parsons ES. The pump will be attached to the well point where 0.375-inch Teflon[®] tubing is used; where PVC points are installed, dedicated high-density polyethylene (HDPE) tubing will be inserted into the point and attached to the pump. Water will be removed until pH, temperature, specific conductivity, and water clarity (turbidity) stabilize. Monitoring point development will occur a minimum of 24 hours prior to sampling.

Development waters will be collected in 55-gallon drums provided by the Base. Filled 55-gallon drums will be staged at the site for later disposal by the Base.

A development record will be maintained for each monitoring point. The development record will be completed in the field by the field scientist. Figure 3.5 is an example of a development record used for similar well installations. Development records will include:

MONITORING POINT DEVELOPMENT RECORD

Page ___ of ___

Job Number: _____
Location: _____
Well Number: _____

Job Name: _____
By: _____ Date: _____
Measurement Datum: _____

Pre-Development Information

Time (Start): _____

Water Level: _____

Total Depth of Well: _____

Water Characteristics

Color: _____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material: _____
pH: _____ Temperature (°F °C): _____
Specific Conductance (µS/cm): _____

Interim Water Characteristics

Gallons Removed _____

pH _____

Temperature (°F °C) _____

Specific Conductance (µS/cm) _____

Post-Development Information

Time (Finish): _____

Water Level: _____

Total Depth of Well: _____

Approximate Volume Removed: _____

Water Characteristics

Color: _____ Clear Cloudy
Odor: None Weak Moderate Strong
Any Films or Immiscible Material: _____
pH: _____ Temperature (°F °C): _____
Specific Conductance (µS/cm): _____

Comments: _____

FIGURE 3.5

MONITORING POINT DEVELOPMENT RECORD

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- Monitoring point number;
- Date and time of development;
- Development method;
- Monitoring point depth;
- Volume of water produced;
- Description of water produced;
- Post development water level and monitoring point depth; and
- Field analytical measurements, including pH and specific conductivity.

3.2.4 Monitoring Point Location and Datum Survey

The location and elevation of the well points will be surveyed soon after completion. The horizontal location will be measured relative to established Base coordinates. Horizontal coordinates will be measured to the nearest 0.1 foot. The elevation of the ground surface adjacent to the protective casing will be measured relative to the USGS msl datum. The ground surface elevation will be measured to the nearest 0.1 foot. Because water levels cannot be measured through the well point tubing, no datum elevation, such as top of casing, will be measured for points installed using 0.375-inch Teflon[®] tubing. If PVC points are installed, the top of the PVC casing will be measured to the nearest 0.01 foot.

3.2.5 Water Level Measurements

Where possible, water levels at monitoring points will be measured within a short time period so that the water level data are comparable. The depth to water below the measurement datum will be measured to the nearest 0.01 foot using an electric water level probe.

3.3 GROUNDWATER SAMPLING PROCEDURES

This section describes the scope of work required for collection of groundwater quality samples at monitoring points. This section also details grab-sampling using

peristaltic pump tubing inserted into the probe rods to obtain single, discrete groundwater samples, if required. All groundwater samples will be obtained using a peristaltic pump and either dedicated Teflon[®]-lined, polyethylene tubing or dedicated HDPE where groundwater levels permit. In order to maintain a high degree of QC during this sampling event, the procedures described in the following sections will be followed.

Sampling will be conducted by qualified scientists and technicians from Parsons ES and the USEPA RSKERL who are trained in the conduct of groundwater sampling, records documentation, and chain-of-custody procedures. In addition, sampling personnel will have thoroughly reviewed this work plan prior to sample acquisition and will have a copy of the work plan available onsite for reference.

The following summarizes the activities that will occur during groundwater sampling:

- Assembly and preparation of equipment and supplies;
- Inspection of the monitoring well or monitoring point integrity including:
 - Protective cover, cap, and lock,
 - External surface seal and pad,
 - Monitoring point stick-up, cap, and datum reference, and
 - Internal surface seal;
- Groundwater sampling, including:
 - Water level and product thickness measurements,
 - Visual inspection of sample water,
 - Monitoring point casing evacuation, and
 - Sample collection;
- Sample preservation and shipment, including:
 - Sample preparation,

- Onsite measurement of physical parameters, and
- Sample labeling;
- Completion of sampling records; and
- Sample disposition.

Detailed groundwater sampling and sample handling procedures are presented in following sections.

3.3.1 Groundwater Sampling Strategy

Groundwater samples will be collected from monitoring points installed during this project and monitoring wells which have been installed at the site during previous investigations. The monitoring point locations for sampling are identified in the following sections. If site conditions prevent the installation of monitoring points, discrete grab samples will be acquired through the probe rod at each of the proposed monitoring point locations. Up to 30 groundwater samples will be collected for laboratory analysis.

3.3.2 Preparation for Sampling

All equipment to be used for sampling will be assembled and properly cleaned and calibrated (if required) prior to arriving in the field. In addition, all record-keeping materials will be gathered prior to leaving the office.

3.3.2.1 Equipment Cleaning

All portions of sampling and test equipment that will contact the sample matrix will be thoroughly cleaned before use. This includes the Geoprobe® rods, water-level probe and cable, lifting line, test equipment for onsite use, and other equipment or portions thereof that will contact the samples. Based on the types of sample analyses to be conducted, the following cleaning protocol will be used:

- Clean with potable water and phosphate-free laboratory detergent (HP-II detergent solutions, as appropriate);
- Rinse with potable water;

- Rinse with reagent-grade isopropyl alcohol;
- Rinse with distilled or deionized water; and
- Air dry the equipment prior to use.

Any deviations from these procedures will be documented in the field scientist's field notebook and on the groundwater sampling form (Figure 3.6). If precleaned, dedicated sampling equipment is used, the cleaning protocol specified above will not be required. Laboratory-supplied sample containers will be cleaned and sealed by the laboratory, and therefore will not need to be cleaned in the field. The type of container provided and the method of container decontamination will be documented in the USEPA mobile analytical laboratory's permanent record of the sampling event.

3.3.2.2 Equipment Calibration

As required, field analytical equipment will be calibrated according to the manufacturer's specifications prior to field use. This applies to equipment used for onsite measurements of oxygen, carbon dioxide, pH, electrical conductivity, temperature, reduction/oxidation potential, sulfate, nitrate, nitrite, ferrous iron (Fe^{2+}), total iron, and manganese. Ferric iron (Fe^{3+}) will be calculated from the concentration of total iron minus ferrous iron.

3.3.3 Sampling Procedures

Special care will be taken to prevent contamination of the groundwater and extracted samples. The two primary ways in which sample contamination can occur are through contact with improperly cleaned equipment and by cross-contamination through insufficient cleaning of equipment between monitoring points. To prevent such contamination, the water level probe and cable used to determine static water levels and total well depths will be thoroughly cleaned before and after field use and between uses at different sampling locations according to the procedures presented in Section 3.3.2.1. In addition to the use of properly cleaned equipment, dedicated polyethylene tubing will be used at each sampling point, and a clean pair of new, disposable nitrile gloves will be worn each time a different monitoring point or monitoring well is sampled. The following paragraphs present the procedures to be followed for groundwater sample collection from monitoring points and monitoring wells. These

SAMPLING LOCATION _____
SAMPLING DATE(S) _____

GROUND WATER SAMPLING RECORD - MONITORING WELL _____
(number)

REASON FOR SAMPLING: ☐ Regular Sampling; ☐ Special Sampling;

DATE AND TIME OF SAMPLING: _____, 19____ a.m./p.m.

SAMPLE COLLECTED BY: _____ of _____

WEATHER: _____

DATUM FOR WATER DEPTH MEASUREMENT (Describe): _____

MONITORING WELL CONDITION:

☐ LOCKED:

☐ UNLOCKED

WELL NUMBER (IS - IS NOT) APPARENT

STEEL CASING CONDITION IS: _____

INNER PVC CASING CONDITION IS: _____

WATER DEPTH MEASUREMENT DATUM (IS - IS NOT) APPARENT

☐ DEFICIENCIES CORRECTED BY SAMPLE COLLECTOR

☐ MONITORING WELL REQUIRED REPAIR (describe): _____

Check-off

1 ☐

EQUIPMENT CLEANED BEFORE USE WITH _____

Items Cleaned (List): _____

2 ☐

PRODUCT DEPTH _____ FT. BELOW DATUM

Measured with: _____

WATER DEPTH _____ FT. BELOW DATUM

Measured with: _____

3 ☐

WATER-CONDITION BEFORE WELL EVACUATION (Describe):

Appearance: _____

Odor: _____

Other Comments: _____

4 ☐

WELL EVACUATION:

Method: _____

Volume Removed: _____

Observations: Water (slightly - very) cloudy

Water level (rose - fell - no change)

Water odors: _____

Other comments: _____

FIGURE 3.6

GROUND WATER
SAMPLING RECORD

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5 [] SAMPLE EXTRACTION METHOD:

[] Bailer made of: _____
 [] Pump, type: _____
 [] Other, describe: _____

Sample obtained is [] GRAB; [] COMPOSITE SAMPLE

6 [] ON-SITE MEASUREMENTS:

Temp: _____ °	Measured with: _____
pH: _____	Measured with: _____
Conductivity: _____	Measured with: _____
Dissolved Oxygen: _____	Measured with: _____
Redox Potential: _____	Measured with: _____
Salinity: _____	Measured with: _____
Nitrate: _____	Measured with: _____
Sulfate: _____	Measured with: _____
Ferrous Iron: _____	Measured with: _____
Other: _____	

7 [] SAMPLE CONTAINERS (material, number, size): _____

8 [] ON-SITE SAMPLE TREATMENT:

[] Filtration: Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

[] Preservatives added:
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____
 Method _____ Containers: _____

9 [] CONTAINER HANDLING:

[] Container Sides Labeled
 [] Container Lids Taped
 [] Containers Placed in Ice Chest

10 [] OTHER COMMENTS: _____

FIGURE 3.6 (Cont.)

**GROUND WATER
SAMPLING RECORD**

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activities will be performed in the order presented below. Exceptions to this procedure will be noted in the field scientist's field notebook.

3.3.3.1 Preparation of Location

Prior to starting the sampling procedure, the area around the monitoring points or monitoring well will be cleared of foreign materials, such as brush, rocks, and debris. These procedures will prevent sampling equipment from inadvertently contacting debris around the sampled monitoring point or monitoring well.

3.3.3.2 Water Level and Total Depth Measurements

Prior to removing any water from the monitoring point or monitoring well, the static water level will be measured, if possible. An electrical water level probe will be used to measure the depth to groundwater below the datum to the nearest 0.01 foot. After measuring the static water level, the water level probe will be slowly lowered to the bottom of the monitoring point or monitoring well and the depth will be measured to the nearest 0.01 foot. Based on these measurements, the volume of water to be purged from the monitoring point or monitoring well will be calculated. Where monitoring points which consist of Teflon[®] tubing casing and stainless steel screens are used, purge volumes will be calculated based on the known screen volume. If free product is encountered, the thickness of the product will be measured if possible. Attempts will be made to sample both within and below the oil lens.

3.3.3.3 Purging Before Sampling

The volume of water contained within the monitoring point or monitoring well casings at the time of sampling will be calculated, and three times the calculated volume will be removed. All purge water will be placed in Base-provided, 55-gallon drums and staged at the site for later disposal by Pope AFB. A peristaltic pump will be used for monitoring point and monitoring well purging.

If a monitoring point or monitoring well is evacuated to a dry state during purging, it will be allowed to recharge, and the sample will be collected as soon as sufficient water is present to obtain the necessary sample quantity. Sample compositing, or sampling over a lengthy period by accumulating small volumes of water at different times to obtain a sample of sufficient volume will not be allowed.

The installed well points require minimal purging before sampling because the water in the well point tubing has little contact with the atmosphere. The sampler will pump enough water to ensure that the water in the tubing has been changed several times and that DO, redox potential, specific conductance, and pH stabilize.

3.3.3.4 Sample Extraction

Dedicated HDPE tubing and a peristaltic pump will be used to extract groundwater samples from the existing monitoring wells. The tubing will be lowered through the well and 0.5-inch ID PVC monitoring point casing into the water gently to prevent splashing. The tubing from the monitoring points constructed of 0.375-inch Teflon® tubing will be connected directly to the peristaltic pump. The sample will be transferred directly into the appropriate sample container. The water will be carefully poured down the inner walls of the sample bottle to minimize aeration of the sample.

At locations where the installation of monitoring points is found to be impossible, inefficient, or inadequate to acquire a credible groundwater sample, grab groundwater sampling will be performed using the Geoprobe®, peristaltic pump, and dedicated HDPE tubing. The tubing will be lowered into a push rod fitted with a slotted tip and a discrete groundwater sample will be acquired.

Unless other instructions are given by the USEPA analytical laboratory, sample containers will be completely filled so that no air space remains in the container. Excess water collected during sampling will be placed into the 55-gallon drums used for monitoring point purge waters and staged at the site for later disposal by Pope AFB.

3.3.4 Onsite Groundwater Parameter Measurement

As indicated in Table 3.1, many of the groundwater chemical parameters will be measured onsite by USEPA personnel. Some of the measurements will be made with direct-reading meters, while others will be made using a HACH® portable colorimeter in accordance with specific HACH® analytical procedures. These procedures are described in the following subsections.

All glassware or plasticware used in the analyses will be cleaned prior to sample collection by thoroughly washing with a solution of Alconox® and water, and rinsing with isopropyl alcohol and deionized water to prevent interference or

cross-contamination between measurements. If concentrations of an analyte are above the range detectable by the titrimetric method, the analysis will be repeated by diluting the groundwater sample with double-distilled water until the analyte concentration falls to a level within the range of the method. All rinseate and sample reagents accumulated during groundwater analysis will be collected in glass containers fitted with screw caps. These waste containers will be clearly labeled to identify their contents and carefully stored for later transfer by Base personnel to an approved disposal facility.

3.3.4.1 Dissolved Oxygen Measurements

DO measurements will be taken using a flow-through chamber. Measurements will be taken before groundwater sample acquisition. When DO measurements are taken in a monitoring point that has not yet been sampled, the monitoring point will be purged until DO levels stabilize.

3.3.4.2 pH, Temperature, and Specific Conductance

Because the pH, temperature, and specific conductance of a groundwater sample can change significantly within a short time following sample acquisition, these parameters will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made in a clean glass container separate from those intended for laboratory analysis, and the measured values will be recorded on the groundwater sampling record (see Figure 3.6). As space allows, probes for these analyses will be placed in the same flow-through cell used for DO measurements.

3.3.4.3 Carbon Dioxide Measurements

Carbon dioxide concentrations in groundwater will be measured in the field by experienced RSKERL scientists via titrimetric analysis using CHEMetrics® Method 4500-CO₂C (10-100 ppm as CO₂).

3.3.4.4 Alkalinity Measurements

Alkalinity in groundwater helps buffer the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. Alkalinity of the groundwater sample will be measured in the field by experienced USEPA RSKERL

scientists via titrimetric analysis using EPA-approved HACH® method 8221 (0-5,000 mg/L as calcium carbonate). Alkalinity of the groundwater will also be measured in the laboratory using USEPA Method 310.1.

3.3.4.5 Nitrate- and Nitrite-Nitrogen Measurements

Nitrate-nitrogen concentrations are of interest because nitrate can act as an electron acceptor during hydrocarbon biodegradation under anaerobic soil or groundwater conditions. Nitrate-nitrogen is also a potential nitrogen source for biomass formation for hydrocarbon-degrading bacteria. Nitrite-nitrogen is an intermediate byproduct in both ammonia nitrification and in nitrate reduction in anaerobic environments.

Nitrate- and nitrite-nitrogen concentrations in groundwater will be measured in the field by experienced USEPA RSKERL scientists via colorimetric analysis using a HACH® DR/700 Portable Colorimeter. Nitrate concentrations in groundwater samples will be analyzed after preparation with HACH® method 8039 (0-30.0 mg/L nitrate). Nitrite concentrations in groundwater samples will be analyzed after preparation with EPA-approved HACH® method 8507 (0-0.35 mg/L nitrite).

3.3.4.6 Sulfate and Sulfide Sulfur Measurements

Sulfate in groundwater is a potential electron acceptor for fuel-hydrocarbon biodegradation in anaerobic environments, and sulfide is resultant after sulfate reduction. The USEPA RSKERL scientists will measure sulfate and sulfide concentrations via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. EPA-approved HACH® methods 8051 (0-70.0 mg/L sulfate) and 8131 (0.60 mg/L sulfide) will be used to prepare samples and analyze sulfate and sulfide concentrations, respectively.

3.3.4.7 Total Iron, Ferrous Iron, and Ferric Iron Measurements

Iron is an important trace nutrient for bacterial growth, and different states of iron can affect the oxidation/reduction potential of the groundwater and act as an electron acceptor for biological metabolism under anaerobic conditions. Iron concentrations will be measured in the field via colorimetric analysis with a HACH® DR/700 Portable Colorimeter after appropriate sample preparation. HACH® method 8008 for total soluble iron (0-3.0 mg/L ferric and ferrous iron) and HACH® method 8146 for ferrous

iron (0-3.0 mg/L) will be used to prepare and quantitate the samples. Ferric iron will be quantitated by subtracting ferrous iron levels from total iron levels.

3.3.4.8 Manganese Measurements

Manganese is a potential electron acceptor under anaerobic environments. Manganese concentrations will be quantified in the field using colorimetric analysis with a HACH® DR/700 Portable Colorimeter. EPA approved HACH® method 8034 (0-20.0 mg/L) will be used to prepare the samples for quantification of manganese concentrations.

3.3.4.9 Reduction/Oxidation Potential

The reduction/oxidation (redox) potential of groundwater is an indicator of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater are usually biologically mediated; therefore, the redox potential of a groundwater system depends upon and influences rates of biodegradation. Redox potential can be used to provide real time data on the location of the contaminant plume, especially in areas undergoing anaerobic biodegradation. The redox potential of a groundwater sample taken inside the contaminant plume should have a redox potential somewhat less than that taken in the upgradient location.

The redox potential of a groundwater sample can change significantly within a short time following sample acquisition and exposure to atmospheric oxygen. As a result, this parameter will be measured in the field in unfiltered, unpreserved, "fresh" water collected by the same technique as the samples taken for laboratory analyses. The measurements will be made as quickly as possible in a clean glass container separate from those intended for laboratory analysis. As space allows, the redox probe will be placed in the same flow-through cell used for DO measurements.

3.4 SAMPLE HANDLING FOR LABORATORY ANALYSIS

This section describes the handling of samples to be performed by Parsons ES and RSKERL personnel from the time of sampling until the samples arrive at the laboratory.

3.4.1 Sample Preservation

The USEPA laboratory support personnel will add any necessary chemical preservatives prior to shipping the containers to the site. Samples will be properly prepared for transportation to the analytical laboratory by placing the samples in a cooler containing ice to maintain a shipping temperature as close to 4 degrees Centigrade (°C) as possible. Samples will be hand delivered promptly to USEPA field laboratory personnel, who will be responsible for shipment of appropriate samples to the RSKERL in Ada, Oklahoma for analysis. Samples will be promptly delivered to the analytical laboratory via overnight courier so that all sample holding times are met.

3.4.2 Sample Container and Labels

Sample containers and appropriate container lids will be provided by the USEPA field laboratory (see Appendix C). The sample containers will be filled as described in Sections 3.3.3.4, and the container lids will be tightly closed. The sample label will be firmly attached to the container side, and the following information will be legibly and indelibly written on the label:

- Facility name;
- Sample identification;
- Sample type (e.g., groundwater);
- Sampling date;
- Sampling time;
- Preservatives added;
- Sample collector's initials; and
- Requested analyses.

3.4.3 Sample Shipment

After the samples are sealed and labeled, they will be packaged for transport to USEPA laboratory. The following packaging and labeling procedures will be followed:

- Package sample so that it will not leak, spill, or vaporize from its container; and
- Cushion samples to avoid breakage; and
- Add ice to container to keep samples cool.

The packaged samples will be delivered by hand to the on-site USEPA laboratory. Delivery will occur shortly after sample acquisition.

3.4.4 Chain-of-Custody Control

After the samples have been collected, chain-of-custody procedures will be followed to establish a written record of sample handling and movement between the sampling site and the analytical laboratory. Each shipping container will have a chain-of-custody form completed in triplicate by the sampling personnel. One copy of this form will be kept by the sample collector after sample delivery to the USEPA laboratory, and the other two copies will be retained at the USEPA RSKERL laboratory. One of the laboratory copies will become a part of the permanent record for the sample and will be returned with the sample analytical results. The chain-of-custody will contain the following information:

- Sample identification number;
- Sample collector's printed name and signature;
- Date and time of collection;
- Place and address of collection;
- Sample matrix;
- Chemical preservatives added;
- Analyses requested;
- Signatures of individuals involved in the chain of possession; and
- Inclusive dates of possession.

The chain-of-custody documentation will be placed inside the shipping container so that it will be immediately apparent to the laboratory personnel receiving the container,

but will not be damaged or lost during transport. The shipping container will be sealed so that it will be obvious if the seal has been tampered with or broken.

3.4.5 Sampling Records

In order to provide complete documentation of the sampling event, detailed records will be maintained by the field scientist. At a minimum, these records will include the following information:

- Sample location (facility name);
- Sample identification;
- Sample location map or detailed sketch;
- Date and time of sampling;
- Sampling method;
- Field observations of
 - Sample appearance, and
 - Sample odor;
- Weather conditions;
- Water level prior to purging;
- Total monitoring well/point depth;
- Purge volume;
- Water level after purging;
- Monitoring well/point condition;
- Sampler's identification;
- Field measurements of pH, temperature, DO, and specific conductivity; and
- Any other relevant information.

Groundwater sampling information will be recorded on a groundwater sampling form. Figure 3.6 shows an example of the groundwater sampling record.

3.4.6 Laboratory Analyses

Laboratory analyses will be performed on all groundwater samples and the QA/QC samples described in Section 5. The analytical methods for this sampling event are listed in Table 3.1. Prior to sampling, arrangements will be made with the USEPA RSKERL laboratory to provide a sufficient number of appropriate sample containers for the samples to be collected. All containers, preservatives, and shipping requirements will be consistent with EPA protocol or those listed in Appendix C of this plan.

USEPA laboratory support personnel will specify the necessary QC samples and notify the laboratory to prepare appropriate QC sample bottles. For samples requiring chemical preservation, preservatives will be added to containers by the laboratory prior to transportation. Containers, ice chests with adequate padding, and cooling media may be sent by the USEPA RSKERL laboratory to the site. Sampling personnel will fill the sample containers and return the samples to the laboratory.

3.5 AQUIFER TESTING

If sufficient data are not available from previous studies at the site, Parsons ES may be required to perform hydraulic conductivity testing. Several monitoring wells at the site are available for slug testing. Well installation and construction information is available for the wells in Metcalf & Eddy (1992). Slug tests will be conducted by Parsons ES personnel to estimate the hydraulic conductivity of the shallow saturated zone. This information is required to accurately estimate the velocity of groundwater and contaminants in the shallow saturated zone. A slug test is a single-well hydraulic test used to determine the hydraulic conductivity of an aquifer in the immediate vicinity of the tested well. Slug tests can be used for both confined and unconfined aquifers that have a transmissivity of less than 7,000 square feet per day (ft^2/day). Slug testing can be performed using either a rising head or a falling head test; for the Pope AFB site, both methods will be used in sequence.

3.5.1 Definitions

- **Hydraulic Conductivity (K).** A quantitative measure of the ability of porous material to transmit water; defined as the volume of water that will flow through

a unit cross-sectional area of porous or fractured material per unit time under a unit hydraulic gradient.

- **Transmissivity (T).** A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity and the saturated thickness.
- **Slug Test.** Two types of testing are possible; a rising head or falling head test. A slug test consists of adding a slug of water or a solid cylinder of known volume to the well to be tested or removing a known volume of water or cylinder and measuring the rate of recovery of water level inside the well. The slug of a known volume acts to raise or lower the water level in the well.
- **Rising Head Test.** A test used in an individual well within the saturated zone to estimate the hydraulic conductivity of the surrounding formation by lowering the water level in the well and measuring the rate of recovery of the water level. The water level may be lowered by pumping, bailing or removing a submerged slug from the well.
- **Falling Head Test.** A test used in an individual well to estimate the hydraulic conductivity of the surrounding formation by raising the water level in the well by insertion of a slug or quantity of water, and then measuring the rate of drop in the water level.

3.5.2 Equipment

The following equipment is needed to conduct a slug test:

- Teflon[®], PVC, or metal slugs,
- One-quarter-inch nylon or polypropylene rope,
- Electric water level indicator,
- Pressure transducer/sensor,
- Field logbook/forms,
- Automatic data recording instrument (such as the Hermit[®] Environmental Data

· Logger, In-Situ, Inc. Model SE1000B or equal).

3.5.3 General Test Methods

Aquifer hydraulic conductivity tests (slug tests) are accomplished by either removal of a slug or quantity of water (rising head) or introduction of a slug (falling head), and then allowing the water level to stabilize while taking water level measurements at closely spaced time intervals.

Because hydraulic testing will be completed on existing wells, it will be assumed that the wells were properly developed and that water levels have stabilized. Slug testing will proceed only after water level measurements show that static water levels are in equilibrium. During the slug test, the water level change should be influenced only by the introduction (or subtraction) of the slug volume. Other factors, such as inadequate well development or extended pumping, etc., may lead to inaccurate results. It is up to the field hydrogeologist to determine when static equilibrium has been reached in the well. The pressure transducer, slugs, and any other down-hole equipment will be decontaminated prior to and immediately after the performance of each slug test using the procedures described in Section 3.2.2.2.

3.5.4 Falling Head Test

The falling head test is the first step in the two-step slug-testing procedure. The following steps describe the falling head test procedures.

1. Decontaminate all downhole equipment prior to initiating the test.
2. Open the well. Where wells are located within the 100-year flood plain and equipped with water tight caps, the well should be unsealed at least 24 hours prior to testing to allow the water level to stabilize. The protective casing will remain locked during this time to prevent vandalism.
3. Prepare the Aquifer Test Data Form (Figure 3.7) with entries for:
 - Borehole/well number,
 - Project number,
 - Project name,

AQUIFER SLUG TEST DATA SHEET

Location _____	Client _____	Well No. _____
Job No. _____	Field Scientist _____	Date _____
Water Level _____	Total Well Depth _____	
Measuring Datum _____	Elevation of Datum _____	
Weather _____	Temp _____	
Comments _____		

[illegible]

m:\forms\slug.doc 4/28/94

FIGURE 3.7

AQUIFER SLUG TEST DATA FORM

Intrinsic Remediation EE/CA
FPTA No. 4
Pope AFB, NC



**PARSONS
ENGINEERING SCIENCE, INC.**

Cary, North Carolina

- Aquifer testing team,
 - Climatic data,
 - Ground surface elevation,
 - Top of well casing elevation,
 - Identification of measuring equipment being used,
 - Page number,
 - Static water level,
 - Date, and
 - Time intervals (0, 1, 3, 5, 7, 9, 10, and 12 minutes and every 3 minutes thereafter through 60 elapsed minutes, then in 10-minute intervals for the next hour, and in 30-minute intervals for the next 3 hours).
4. Measure the static water level in the well to the nearest 0.01 foot.
 5. Lower the decontaminated pressure transducer into the well and allow the displaced water to return to its static level. This can be determined by periodic water level measurements until the static water level in the well is within 0.01 foot of the original static water level.
 6. Lower the decontaminated slug into the well to just above the water level in the well.
 7. Turn on the data logger and quickly lower the slug below the water table being careful not to disturb the pressure transducer. Follow the owners' manual for proper operation of the data logger.
 8. Terminate data recording when the water level stabilizes in the well.

3.5.5 Rising Head Test

After completion of the falling head test, the rising head test will be performed. The following steps describe the rising head slug test procedures.

1. Measure the static water level in the well to the nearest 0.01 foot to ensure that it has returned to the static water level.
2. Initiate data recording and quickly withdraw the slug from the well. Follow the owners' manual for proper operation of the data logger.
3. Terminate data recording when the water level stabilizes in the well. Remove the pressure transducer from the well and decontaminate.

3.5.6 Slug Test Data Analysis

Data obtained during slug testing will be analyzed using AQTESOLV™ (Geraghty & Miller, Inc., 1991) and the method of Hvorslev (1951) for confined aquifers, or the method of Bouwer and Rice (1976) and Bouwer (1989) for unconfined conditions. Based on a review of site hydrogeology at the FPTA No. 4 site (Section 2.1.2), unconfined conditions dominate the site and the Bouwer and Rice method will be used for most of the hydraulic conductivity testing.

SECTION 4

REMEDIAL OPTION EVALUATION AND EE/CA REPORT

Upon completion of field work, the Bioplume II numerical groundwater model will be used to determine the fate and transport of fuel hydrocarbons dissolved in groundwater at the FPTA No. 4 site. Based upon model predictions of contaminant concentration and distribution through time, and upon potential exposure pathways, the potential risk to human health and the environment will be assessed on the basis of regulatory action levels. If it is shown that intrinsic remediation of BTEX compounds at the site is sufficient to reduce the potential risk to human health and the environment to acceptable levels, Parsons ES will recommend implementation of the intrinsic remediation option. If intrinsic remediation is chosen, Parsons ES will prepare a site-specific, long-term monitoring plan that will specify the location of point-of-compliance monitoring wells and sampling frequencies.

If the intrinsic remediation remedial option is deemed inappropriate for use at this site, institutional controls such as groundwater or land use restrictions will be evaluated to determine if they will be sufficient to reduce the risk to human health and the environment to acceptable levels. If institutional controls are inappropriate, remedial options which could reduce risks to acceptable levels will be evaluated and the most appropriate remedial options will be recommended. Since a free-product recovery system is already installed and operated at the site, Parsons ES will review operational data for this system to determine whether additional improvements are warranted. Other potential remedial options include, but are not limited to, groundwater pump-and-treat, enhanced biological treatment, bioventing, biosparging, and *in situ* reactive barrier walls. The reduction in dissolved BTEX that should result from remedial activities will be used to produce a new input file for the Bioplume II model. The model will then be used to predict the BTEX plume reduction that should result from remedial actions.

Upon completion of Bioplume II modeling and remedial option selection, a report detailing the results of the modeling and remedial option selection will be prepared. This report will follow the outline presented in Table 4.1 and will contain an introduction, site description, identification of remediation objectives, description of remediation alternatives, an analysis of remediation alternatives, and the recommended

TABLE 4.1
INTRINSIC REMEDIATION EE/CA REPORT OUTLINE
FPTA NO. 4
POPE AFB, NC

INTRODUCTION

Scope and Objectives
Site Background

SITE CHARACTERIZATION ACTIVITIES

Geoprobe, Sampling, and Aquifer Testing Procedures

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

Surface Features
Regional Geology and Hydrogeology
Site Geology and Hydrogeology
Climatological Characteristics

NATURE AND EXTENT OF CONTAMINATION

Source Characterization
Soil Chemistry
 Residual-Phase Contamination
 Total Organic Carbon
Ground Water Chemistry
 LNAPL Contamination
 Dissolved Contamination
 Ground Water Geochemistry
 Expressed Assimilative Capacity

GROUND WATER MODEL

Model Description
Conceptual Model Design and Assumptions
Initial Model Setup
Model Calibration
Sensitivity Analysis
Model Results
Conclusions

COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

Remedial Alternative Evaluation Criteria
 Long-Term Effectiveness
 Implementability (Technical, Administrative)
 Cost (Capital, Operating, Present Worth)
Factors Influencing Alternatives Development
 Program Objectives
 Contaminant Properties
 Site-Specific Conditions
Brief Description of Remedial Alternatives
 Intrinsic Remediation with Long-Term Monitoring
 Other Alternatives
Evaluation of Alternatives
Recommended Remedial Approach

TABLE 4.1
INTRINSIC REMEDIATION EE/CA REPORT OUTLINE
FPTA NO. 4
POPE AFB, NC

LONG-TERM MONITORING PLAN

Overview
Monitoring Networks
Ground Water Sampling

CONCLUSIONS AND RECOMMENDATIONS

How does the recommended technology offer adequate protection for less cost.

APPENDICES: Supporting Data and Documentation

Site-Specific Bioplume II Model Input and Results

remedial approach. This report will also contain the results of the site characterization activities described herein and a description of the Bioplume II model developed for this site.

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

Field QA/QC procedures will include collection of field duplicates and rinseate, field and trip blanks; decontamination of the water level probe and cable; use of analyte-appropriate containers; and chain-of-custody procedures for sample handling and tracking. All samples to be transferred to the USEPA RSKERL laboratory for analysis will be clearly labeled to indicate sample number, location, matrix (e.g., groundwater), and analyses requested. Samples will be preserved in accordance with the analytical methods to be used, and water sample containers will be packaged in coolers with ice to maintain a temperature of 4°C.

All field sampling activities will be recorded in a bound, sequentially paginated field notebook in permanent ink. All sample collection entries will include the date, time, sample locations and numbers, notations of field observations, and the sampler's name and signature. Field QC samples will be collected in accordance with the program described below, and as summarized in Table 5.1.

QA/QC sampling will include collection and analysis of duplicate samples, rinseate blanks, field/trip blanks, and matrix spike samples. Internal laboratory QC analyses will involve laboratory control samples (LCSs) and laboratory method blanks (LMBs). QA/QC objectives for each of these samples, blanks, and spikes are described below.

Groundwater samples from the Geoprobe® system should provide sufficient volume for some duplicate analysis. Refer to Appendix C for further details on volume requirements.

One rinseate sample will be collected for every 10 or fewer groundwater samples collected. Because disposable bailers may be used for this sampling event, the rinseate sample will consist of a sample of distilled water poured into a bailer and subsequently transferred into a sample container provided by the laboratory. Rinseate samples will be analyzed for VOCs only.

TABLE 5.1
QA/QC SAMPLING PROGRAM
INTRINSIC REMEDIATION EE/CA
FPTA NO. 4
POPE AFB, NC

QA/QC Sample Types	Frequency to be Collected and/or Analyzed	Analytical Methods
Duplicates/Replicates	10 % of Samples per Matrix ^{a/}	VOCs, TPH
Rinseate Blanks	10 % of Ground Water Samples ^{a/}	VOCs
Field Blanks	5 % of Ground Water Samples ^{a/}	VOCs
Trip Blanks	One per shipping cooler containing VOC samples	VOCs
Matrix Spike Samples	Once per sampling event	VOCs
Laboratory Control Sample	Once per method per medium	Laboratory Control Charts (Method Specific)
Laboratory Method Blanks	Once per method per medium	Laboratory Control Charts (Method Specific)

^{a/} Rounded to the next highest whole number.

A field blank will be collected for every 20 or fewer groundwater samples to assess the effects of ambient conditions in the field. The field blank will consist of a sample of distilled water poured into a laboratory-supplied sample container while sampling activities are underway. The field blank will be analyzed for VOCs.

A trip blank will be analyzed to assess the effects of ambient conditions and conditions on sampling results during the transportation of samples. The trip blank will be prepared by the laboratory and will be transported inside one of the coolers containing samples. This sample will be analyzed for VOCs.

Matrix spikes will be prepared in the laboratory and used to establish matrix effects for samples analyzed for VOCs.

Laboratory control samples (LCSs) and laboratory method blanks (LMBs) will be prepared internally by the laboratory and will be analyzed each day samples from the site are analyzed. Samples will be reanalyzed in cases where the LCS or LMB are out of the control limits. Control charts for LCSs and LMBs will be developed by the laboratory and monitored for the analytical methods used.

SECTION 6

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APPENDIX A

SOIL ANALYTICAL DATA

TABLE A1a
SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 1

SAMPLE LOCATION ID:	BH1-1	BH1-1	BH1-1	BH1-2	BH1-2 (D)	BH1-2	BH1-2
DEPTH (ft):	0-2	2-4	4-6	0-2	0-2	2-4	4-6
SAMPLE DATE:	8-7-89	8-7-89	8-7-89	8-4-89	8-4-89	8-4-89	8-5-89
LAB SAMPLE NO:	8909L275	8908L275	8908L275	8908L275	8908L275	8908L275	8908L275
ANALYTE	CONCENTRATION (mg/kg)						
METALS*							
Pb	20	4.6	7.2	7.3	4.7	5.3	3.2
TPHS	10	--	--	--	7	5.9	--
VOCs							
Toluene		--	0.013	--	--	--	--
SVOCs							
bis(2-Ethylhexyl) phthalate		--	--	--	--	--	1

SAMPLE LOCATION ID:	BH1-3	BH1-3	BH1-4	BH1-4	BH1-5	BH1-5	BH1-6
DEPTH (ft):	0-2	2-4	0-2	2-4	0-2	2-4	0-2
SAMPLE DATE:	8-4-89	8-4-89	8-8-89	8-8-89	8-8-89	8-8-89	8-7-89
LAB SAMPLE NO:	8908L275	8908L275	8908L298	8908L298	8908L298	8908L298	8908L298
ANALYTE	CONCENTRATION (mg/kg)						
METALS*							
Pb	20	4.3	2.1	3.9	2.3	6	34.1
TPHS	10	--	--	21	--	62	1500
VOCs							
4-Methyl-2-pentanone		--	--	--	--	--	0.055
SVOCs		--	--	--	--	--	--

TABLE A1a (Continued)
SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 1

SAMPLE LOCATION ID:	BH1-6	BH1-6	BH1-6	BH1-7	BH1-7	BH1-7	BH1-7	BH1-8
DEPTH (ft):	2-4	2-4 (D)	4-6	0-2	4-6	8-10	8-8-89	0-2
SAMPLE DATE:	8-7-89	8-7-89	8-7-89	8-8-89	8-8-89	8-8-89	8-8-89	8-8-89
LAB SAMPLE NO:	8908L298	8908L298	8908L298	8908L333	8908L333	8908L333	8908L333	8908L298
ANALYTE	ARAR	CONCENTRATION (mg/kg)						
METALS*								
Pb	20	43.7	26.2	3.2	5.9	1.8	1.6	21.2
TPHs	10	8100	4800	82	110	1600	310	1300
VOCs								
Benzene		--	--	--	--	--	--	--
4-Methyl-2-pentanone		0.012	0.76J	0.26	--	15	7.1	--
Tetrachloroethene		--	--	--	--	--	1.2J	--
2-Hexanone		--	--	0.078B	--	50	24	--
Ethylbenzene		--	0.33J	--	--	1.1J	1.1J	--
Xylene (total)		--	1.1	--	--	5.1J	4.4	--
SVOCs								
Fluorene		--	--	--	--	--	--	0.39
Phenanthrene		--	--	--	--	--	--	3.1
Anthracene		--	--	--	--	--	--	0.76
Fluoranthene		--	--	--	--	--	--	3.8
Pyrene		--	--	--	--	--	--	2.3
Benzo(a)anthracene		--	--	--	--	--	--	1.6
Chrysene		--	--	--	--	--	--	1.8
Benzo(b)fluoranthene		--	--	--	--	--	--	1.2
Benzo(k)fluoranthene		--	--	--	--	--	--	0.94
Benzo(a)pyrene		--	--	--	--	--	--	1.2
Napthalene		--	--	--	--	0.54	--	--

TABLE A1a (Continued)
SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 1

SAMPLE LOCATION ID:	BH1-8	BH1-8 (D)	BH1-8	BH1-9	BH1-9	BH1-9	BH1-9	BH1-10
DEPTH (ft):	2-4	2-4	4-6	0-2	2-4	4-6	0-2	0-2
SAMPLE DATE:	8-8-89	8-8-89	8-8-89	8-9-89	8-9-89	8-9-89	8-9-89	8-10-89
LAB SAMPLE NO:	8908L298	8908L298	8908L298	8908L333	8908L333	8908L333	8908L333	8908L345
ANALYTE	ARAR	CONCENTRATION (mg/kg)						
METALS*								
Pb	20	12.7	8.5	6.1	17.8	5.4	6.3	4.5
TPHs	10	3100	3500	1000	170	1900	14,000	310
VOCs								
4-Methyl-2-pentanone		4.3J	--	--	--	15	160	--
2-Butanone		--	--	--	--	--	25J	--
2-Hexanone		40	--	--	--	61	360	--
1,1,2,2-Tetrachloroethane		0.91J	--	--	--	--	--	--
Toluene		--	--	--	--	2.4J	31	--
Ethylbenzene		3.8	--	--	--	4.8	34	--
Xylene (total)		28	--	--	--	26	50	--
SVOCs								
Naphthalene		3.2	4.9	0.98	--	2.4	15	--
Fluorene		--	--	--	--	--	0.68J	--
Phenanthrene		--	0.35J	--	--	--	0.75J	--
Di-n-butylphthalate		--	--	--	--	--	0.38J	--

TABLE A1a (Continued)
SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 1

SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES									
SAMPLE LOCATION ID:	BH1-10	BH1-10 (D)	BH1-11	BH1-11	BH1-12	BH1-12	BH1-12	BH1-12	BH1-12
DEPTH (ft):	2-6	2-6	0-2	2-4	0-2	0-2	2-4	2-4	8-10
SAMPLE DATE:	8-10-89	8-10-89	8-12-89	8-12-89	8-12-89	8-12-89	8-12-89	8-12-89	8-12-89
LAB SAMPLE NO:	8908L345	8908L345	8908L378	8908L378	8908L378	8908L378	8908L378	8908L378	8908L378
ANALYTE	ARAR	CONCENTRATION (mg/kg)							
METALS									
Pb	20	2.8	2.8	23.1	4.6	0.76	7.1	--	4.9
TPHs	10	56	45	3700	7400	3200	39	200	2100
VOCs									
2-Hexanone		--	--	60	12	--	--	--	440
Toluene		--	--	4.3	1.9J	--	--	--	91
Ethylbenzene		--	--	3.6	2.6J	--	--	--	60
Methylene Chloride		--	--	--	--	--	--	--	43B
Acetone		--	--	--	--	--	--	--	58B
Benzene		--	--	--	--	--	--	--	6.4J
Xylene (total)		--	--	23	18	--	--	--	34
4-Methyl-2-Pentanone		--	--	4.5J	--	--	--	--	94
SVOCs									
Naphthalene		--	--	0.39	3.1	3.1	--	--	30
Fluorene		--	--	--	0.56	0.35J	--	--	--
Phenanthrene		--	--	--	0.79	0.47	--	--	--

TABLE A1a (Continued)
SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 1

SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 2									
SAMPLE LOCATION ID:		BH1-13	BH1-13	BH1-19	BH1-19	BH1-19 (D)	MW1-14	MW1-14	MW1-14
DEPTH (ft):		0-2	2-4	0-2	2-4	2-4	0-2	0-2	18-24
SAMPLE DATE:		8-9-89	8-9-89	8-9-89	8-9-89	8-9-89	8-14-89	8-14-89	8-14-89
LAB SAMPLE NO:		8908L333	8908L333	8908L333	8908L333	8908L333	8908L275	8908L275	8908L275
ANALYTE		ARAR	CONCENTRATION (mg/kg)						
METALS									
Pb	20	20.6	178	4.5	3.2	4	5.1	2.6	
TPHs	10	4300	44,000	38	48	44	4.8	--	
VOCs									
Trans-1,3-Dichloro-propene		0.86J	--	--	--	--	--	--	
2-Hexanone		19	--	--	--	--	--	--	
Benzene		9.9MA	--	--	--	--	--	--	
Toluene		10	--	--	--	--	--	--	
4-Methyl-2-Pentanone		--	12MA	--	--	--	--	--	
Ethylbenzene		4.2	--	--	--	--	--	--	
Xylene (total)		27	--	--	--	--	--	--	
SVOCs									
Fluorene		--	3.1J	--	--	--	--	--	
Naphthalene		5	56	--	--	--	--	--	
Phenanthrene		0.47J	--	--	--	--	--	--	

TABLE A1a (Continued)
SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 1

SAMPLE LOCATION ID:	MW1-14	MW1-15	MW1-15	MW1-15	MW1-15(D)	MW1-15	MW1-16	MW1-16	MW1-16
DEPTH (ft):	8-10	0-2	10-12	4-6	8-14-89	8-21-89	4-6	8-21-89	8-10
SAMPLE DATE:	8-14-89	8-14-89	8-14-89	8-14-89	8-14-89	8-21-89	8-21-89	8-21-89	8-21-89
LAB SAMPLE NO:	8908L409	8908L409	8908L409	8908L409	8908L409	8908L472	8908L472	8908L472	8908L472
ANALYTE	ARAR	CONCENTRATION (mg/kg)							
METALS*									
Pb	20	1.2	16.8	1.4	1.7	1.2	22.5	7.8	1.4
TPHs	10	4.9	3500	5.1	4.8	32	190	83	8.8
VOCs	--	--	--	--	--	--	--	--	--
SVOCs									
Naphthalene	--	--	0.66	--	--	--	--	--	--
bis(2-Ethyl-hexyl) phthalate	--	--	--	--	--	--	0.35JB	0.58JB	--

TABLE A1a (Continued)
SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT
SAMPLES AT SITE 1

SAMPLE LOCATION ID:	MW1-17	MW1-18	MW1-18	MW1-18	MW1-18
DEPTH (ft):	4-6	0-2	4-6	8-10	8-10
SAMPLE DATE:	8-22-89	8-23-89	8-23-89	8-23-89	8-23-89
LAB SAMPLE NO:	8908L472	8908L511	8908L511	8908L511	8908L511
ANALYTE	ARAR	CONCENTRATION (mg/kg)			
METALS*					
Pb	20	2.4	2.9	2	1.5
TPH	10	150	61	38	40
VOCs					
Toluene	--	--	0.009	0.006	--
SVOCs					
bis(2-ethylhexyl) phthalate		0.42JB	0.51	--	--

SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 1

TABLE A1a (Continued)							
SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 1							
SAMPLE LOCATION ID:	TP1-1	TP1-1	TP1-2	TP1-2	TP1-3	TP1-3	TP1-3
DEPTH (ft):	5-7	2-4	7-8	0-8	5-6	0-5	
SAMPLE DATE:	1-21-92	1-21-92	1-21-92	1-21-92	1-21-92	1-21-92	1-21-92
LAB SAMPLE NO:	9201L087	9201L087	9201L087	9201L087	9201L087	9201L087	9201L087
ANALYTE	ARAR	CONCENTRATION (mg/kg)					
METALS*							
Cr	100	6.2	8.3	--	--	6.9	5.7
Pb	20	1.6 J	133 J	1.4 J	8.7 J	3.0 J	2.3 J
TPHs	10	17	11,000	--	29	--	--
VOCs							
Ethylbenzene		--	1.7	--	--	--	--
Xylene (total)		--	12	--	--	--	--
Methylene chloride		0.008	--	0.007	0.007 J	0.007	0.008
SVOCs		NA	NA	NA	NA	NA	NA

SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 1

TABLE A1a (Continued)									
SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 1									
SAMPLE LOCATION ID:	TP1-4	TP1-4	TP1-5	TP1-5	TP1-6	TP1-6	TP1-6	TP1-6 (D)	
DEPTH (ft):	7.5-8	0-8	7-8	0-8	7-7.5	0-8.5	0-8.5	0-8.5	
SAMPLE DATE:	1-22-92	1-22-92	1-22-92	1-22-92	1-22-92	1-22-92	1-22-92	1-22-92	
LAB SAMPLE NO:	9210L097	9201L097	9201L097	9201L097	9201L097	9201L097	9201L097	9201L097	
ANALYTE	ARAR	CONCENTRATION (mg/kg)							
METALS*									
Cr	100	--	6.5	--	--	--	--	--	--
Pb	20	1.9 J	2.3 J	56.7 J	7.0 J	7.75 J	8.0 J	8.8 J	
TPHs	10	--	15	3,200	11,000	12,000	18,000	21,000	
VOCs									
Acetone		0.013	--	--	11 J	--	--	--	--
Benzene		0.026	--	--	--	--	--	--	--
Toluene		--	--	49 J	35 J	5.7	95	82	
Ethylbenzene		0.019	--	29	25 J	4.3	49	54	
Xylene (total)		0.074	--	180 J	150 J	27	300	310	
1,2-Dichlorobenzene		--	--	--	--	0.79	--	9.6	
1,4-Dichlorobenzene		--	--	2.9 J	--	1.3	12	15	
SVOCs		NA	NA	NA	NA	NA	NA	NA	NA

TABLE A1a (Continued)
SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 1

SAMPLE LOCATION ID:	LE1-1	LE1-2	LE1-3	SE1-3	SE1-3 (D)	SE1-4
	0-0.3	0-0.3	0-0.3	1-1.5	1-1.5	1-1.5
DEPTH (ft):						
SAMPLE DATE:	9-25-89	9-25-89	9-25-89	1-28-92	1-28-92	1-28-92
LAB SAMPLE NO:	89091884	89091884	89091884	9201L156	9201L156	9201L156
ANALYTE	CONCENTRATION (mg/kg)					
	ARAR					
METALS*						
Cr	100	NA	NA	5.2	--	--
Pb	20	5.1	2.2	2.4 J	1.8 J	54.6 J
TPHs	10	--	--	--	--	1100
VOCs						
Acetone		0.18	0.14J	0.025J	--	--
Carbon Disulfide		0.018J	--	0.007J	--	--
Benzene		--	--	0.01J	0.076	0.032
Ethylbenzene		--	--	0.027J	0.072	0.031
Xylene (total)		--	--	0.046J	0.31	0.10
SVOCs		--	--	--	NA	NA
Di-n-butylphthalate		0.75JMA	--	--		
bis(2-Ethylhexyl) phthalate		11B	3.8MA	--		

TABLE A1a (Continued)
SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT SAMPLES AT SITE 1

SAMPLE LOCATION ID:		BH1-20	BH1-20	BH1-21	BH1-21(D)	BH1-21	BH1-22	BH1-22
DEPTH (ft):		0-4	6-8	0-2	0-2	4-8	0-2	6-8
SAMPLE DATE:		1-25-92	1-25-92	1-26-92	1-26-92	1-26-92	1-26-92	1-27-92
LAB SAMPLE NO:		9201L136	9201L136	9201L143	9201L143	9201L143	9201L143	9201L143
ANALYTE		CONCENTRATION (mg/kg)						
ARAR								
METALS*								
Cr	100	--	--	--	--	9.0	6.1	6.9
Pb	20	9.9	2.2	32.3 J	36.7 J	7.4 J	4.5	3.8
TPHs	10	5.3	5.1	7600	8200	4800	9.1	13
VOCS								
Toluene		--	--	1.41 J	8.9	100 J	0.038	--
Ethylbenzene		--	--	--	5.9	37 J	--	--
Xylene (total)		--	--	0.51 J	49	720 J	--	--
1,2-Dichlorobenzene		--	--	--	1.2 J	3.2 J	--	--
1,3-Dichlorobenzene		--	--	1.4	2.3	5.9 J	--	--
SVOCs		NA	NA	NA	NA	NA	NA	NA

TABLE A1a (Continued)
SUMMARY OF CONSTITUENTS DETECTED IN SOIL AND SEDIMENT
SAMPLES AT SITE 1

SAMPLE LOCATION ID:	BH1-23	BH1-23	BH1-23	BH1-24	BH1-24
DEPTH (ft):	0-4	4-6	1-28-92	0-2	2-4
SAMPLE DATE:	1-28-92	1-28-92	1-28-92	2-4-92	2-4-92
LAB SAMPLE NO:	9201L156	9201L156	9201L156	9201L223	9201L223
ANALYTE	ARAR	CONCENTRATION (mg/kg)			
METALS*					
Cr	100	6.4	--	6.4	--
Pb	20	3.3 J	5.0 J	10.6 J	2.7 J
TPHs	10	--	--	40	18
VOCs					
Acetone		--	--	--	0.21
Benzene		--	--	--	0.081
Ethylbenzene		--	--	--	0.024
Xylene (total)		--	--	--	0.099
SVOCs		NA	NA	NA	NA

Notes:

B = Compound detected in blank
 (D) = Duplicate Sample
 -- = Not Detected
 NA = Not Analyzed
 J = Estimated Quantity
 * = Only the detections of the 8 RCRA metals are reported
 MA = Method Blank Approximation

APPENDIX B

GROUNDWATER ANALYTICAL DATA

TABLE A1b
SUMMARY OF CONSTITUENTS DETECTED IN WATER SAMPLES AT SITE 1

SAMPLE LOCATION ID:	MW1-14	MW1-14 (D)	MW1-14	MW1-14	MW1-15	MW1-15
SCREEN DEPTH (ft):	4-14	4-14	4-14	4-14	4-14	4-14
SAMPLE DATE:	9-19-89	9-19-89	9-20-90	2-5-92	9-19-89	9-20-90
LAB SAMPLE NO:	8909L801	8909L801	9009L837	9202L248	8909L853	9009L837
ANALYTE	ARAR	CONCENTRATION (µg/L)				
METALS*						
Cr (total)	50	NA	--	--	NA	--
Pb (total), Pb (soluble)	15	73.2, --	--, --	--, --	10.5, --	--, --
TPHs (mg/L)		--	--	--	--	--
VOCs						
Benzene	1.0	--	--	--	1.3	1.8
Trichloroethene	2.8	--	--	--	3.4	--
SVOCs		--	NA	NA	--	NA

TABLE 11b (Continued)
SUMMARY OF CONSTITUENTS DETECTED IN WATER SAMPLES AT SITE 1

SUMMARY OF CONSTITUENTS DETECTED IN WATER SAMPLES AT SITE 1						
SAMPLE LOCATION ID:	MW1-15 (D)	MW1-15	MW1-16	MW1-16	MW1-16	MW1-17
SCREEN DEPTH (ft):	4-14	4-14	4-14	4-14	4-14	3.5-13.5
SAMPLE DATE:	9-20-90	2-6-92	9-24-89	9-20-90	2-5-92	9-24-89
LAB SAMPLE NO:	9009L837	9202L259	8909L884	9009L837	9202L248	8909L884
ANALYTE	ARAR	CONCENTRATION (µg/L)				
METALS						
Pb (total), Pb (soluble)	15	--,--	6.2 J,--	27.3,--	--,--	98.8,--
TPHs (mg/L)		--	--	1.2	--	5.7
VOCs						
Benzene	1.0	2.1	--	63	91	100
Toluene	1000	--	--	--	1.9	9.6
Ethylbenzene	29	--	--	83	110	120
Xylene (total)	400	--	--	330	510	490
1,2-Dichlorobenzene		NA	--	NA	NA	1.8
1,4-Dichlorobenzene	75	NA	--	NA	NA	2.5
Trichloroethene	2.8	NA	5	NA	NA	--
1,2 Dichloroethene	70	NA	--	NA	NA	6.1
Vinyl chloride	0.015	NA	--	NA	NA	11
SVOCs		NA	NA			NA
Napthalene				30	18	
2,4-Dimethylphenol				--	--	
						55
						25

TABLE A1b (Continued)
SUMMARY OF CONSTITUENTS DETECTED IN WATER SAMPLES AT SITE 1

SUMMARY OF CONSTITUENTS DETECTED IN WATER SAMPLES						
SAMPLE LOCATION ID:	MW1-17	MW1-17 (D)	MW1-17	MW1-18	MW1-18	MW1-18
SCREEN DEPTH (ft):	3.5-13.5	3.5-13.5	3.5-13.5	4-14	4-14	4-14
SAMPLE DATE:	9-20-90	9-20-90	2-6-92	9-24-89	9-19-90	2-5-92
LAB SAMPLE NO:	9009L837	9009L837	9202L296	8909L884	9009L811	9202L248
ANALYTE	ARAR	CONCENTRATION (µg/L)				
METALS:						
Cr (total) Cr (soluble)	50	--,NA	NA	40.1,--	--,NA	--,NA
Pb (total), Pb (soluble)	15	66,--	NA	624,--	226,13.4	6.0 J,NA
TPHs (mg/L)		--	NA	--	--	--
VOCs						
Benzene	1.0	450	520	130	--	--
Toluene	1000	1.9	10	--	--	--
Ethylbenzene	29	240	310	73	--	--
Xylene (total)	400	790	980	250	--	--
SVOCs			NA	NA	NA	NA
Napthalene		53			--	
2,4-Dimethylphenol		42			--	

TABLE A1b .tinued)
SUMMARY OF CONSTITUENTS DETECTED IN WATER SAMPLES AT SITE 1

SUMMARY OF CONSTITUENTS DETECTED IN WATER SAMPLES AT SITE 1						
SAMPLE LOCATION ID:	MW1-20	MW1-21	MW1-21(D)	MW1-22	MW1-23	MW1-24
SCREEN DEPTH (ft):	9-19	9-14	9-14	4.5-14.5	3.25-13.25	3.5-13.5
SAMPLE DATE:	2-5-92	2-8-92	2-8-92	2-8-92	2-9-92	2-9-92
LAB SAMPLE NO:	9202L248	9202L296	9202L296	9202L296	9202L296	9202L296
ANALYTE	ARAR	CONCENTRATION (µg/L)				
METALS*						
Cr (total), Cr (soluble)	50	--,NA	39.8,---	65.2,NA	--,NA	--,NA
Pb (total), Pb (soluble)	15	--,NA	70.4 J,5.3	79.0,NA	--,NA	7.4,NA
TPHs (mg/L)		--	15	26	--	1.1
VOCs						
Benzene	1.0	--	1600	1400	40	610 J
Toluene	1000	--	4200	3400	2.0	91 J
Ethylbenzene	29	--	540	610	22	240 J
Xylene (total)	400	--	3600	2900	100 J	1000 J
1,2-Dichlorobenzene		--	33	33	1.2	7.1
1,4-Dichlorobenzene	75	--	50	47	1.7	10
Trichloroethene	2.8	--	2.7	2.4	--	--
Tetrachloroethene	0.7	--	4.8	4.7	--	--
Vinyl Chloride	0.015	--	1.0	0.66	--	1.5
1,1-Dichloroethene	7	--	1.4	0.63	--	--
1,2-Dichloroethene	7	--	110	110	--	55
1,1-Dichloroethane		--	11	8.3	--	2.8
1,2-Dichloroethane	0.38	--	6.6	4.6	--	--
1,1,1-Trichloroethane	200	--	7.9	5.1	--	--
1,1,2-Trichloroethane		--	5.6	5.2	--	--
1,2-Dichloropropane	0.56	--	1.4	1.3	--	--
1,1,2,2-Tetrachloroethane		--	0.59	0.52	--	--
Chloroform	0.19	--	4.3	3.7	--	--
Bromoform	0.19	--	1.2	--	--	--
SVOCs		NA	NA	NA	NA	NA

TABLE A1b (Continued)
SUMMARY OF CONSTITUENTS DETECTED ... WATER SAMPLES AT SITE 1

TABLE A1b (Continued) SUMMARY OF CONSTITUENTS DETECTED ... WATER SAMPLES AT SITE 1						
SAMPLE LOCATION ID:	LE1-1	LE1-2	LE1-2(D)	LE1-3	SW1-3	SW1-4
DEPTH (ft):	0 -0.3	0 -0.3	0 -0.3	0 -0.3	0 -0.3	0 -0.3
SAMPLE DATE:	9-25-89	9-25-89	9-25-89	9-25-89	1-28-92	1-28-92
LAB SAMPLE NO:	8909L844	8909L884	8909L884	8909L884	9201L156	9201L156
ANALYTE	ARAR	CONCENTRATION (µg/L)				
METALS						
Pb (total)	15	--	10.5	10.2	--	8.6
TPHs (mg/L)	--	--	1.1	--	2.8	--
VOCs						
Benzene	1.0	--	2.4	4	69	7
Ethylbenzene	29	--	--	--	66	8
Xylene (total)	400	--	1.8	2.6	290	34
SVOCs						
Napthalene	--	--	--	--	22	--

Notes:

- (D) = Duplicate Sample
 -- = Not Detected
 NA = Not Analyzed
 J = Estimated Quantity
 * = Only the detections of the 8 RCRA metals are reported

APPENDIX C

**CONTAINERS, PRESERVATIVES, PACKAGING, AND SHIPPING
REQUIREMENTS FOR GROUNDWATER SAMPLES**

TABLE C
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
FPTA NO. 4
POPE AFB, NC

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Volatile organics	Gas chromatography/mass spectrometry method SW8240.	Handbook method	Data is used to determine the extent of chlorinated solvent and aromatic hydrocarbon contamination, contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon®-lined cap; cool to 4°C	Fixed-base
Soil	Dehydrogenase enzyme activity (optional)	Colorimetric RSKSOP-100	Reduction of added triphenyltetrazolium chloride by soil microbes is measured colorimetrically; analyze immediately	An indicator of the presence of soil microbes, which are necessary for bioremediation to occur	At the beginning of the project	Collect 100 g of soil in a glass container	Field
Soil	Aromatic hydrocarbons (benzene, toluene, ethylbenzene, and xylene [BTEX]; trimethylbenzene isomers)	Purge and trap gas chromatography (GC) method SW8020	Handbook method modified for field extraction of soil using methanol	Data is used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data are used to determine the extent of soil contamination, the contaminant mass present, and the need for source removal	Each sampling round	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base

TABLE C (CONTINUED)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
FPTA NO. 4
POPE AFB, NC

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.5–15 percent TOC	Relatively high amounts of TOC may be indicative of a reducing environment and may indicate the need for analysis of electron acceptors associated with that environment; the rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the saturated zone soil; the rate of release of petroleum contaminants from the source into groundwater is dependent (in part) on the amount of TOC in the vadose zone soil	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C	Fixed-base
Soil	Moisture	ASTM D-2216	Handbook method	Data are used to correct soil sample analytical results for moisture content (e.g., report results on a dry weight basis)	Each soil sampling round	Use a portion of soil sample collected for another analysis	Fixed-base
Soil	Grain size distribution	ASTM D422	Procedure provides a distribution of grain size by sieving	Data are used to infer hydraulic conductivity of aquifer, and are used in calculating sorption of contaminants	One time during life of project	Collect 250 g of soil in a glass or plastic container; preservation is unnecessary	Fixed-base
Soil gas	Carbon dioxide content of soil gas	Nondispersive infrared instrument operating over the range of approximately 0.1–15 percent	Soil gas carbon dioxide may be produced by the degradation of petroleum hydrocarbons	Data used to understand the carbon dioxide concentration gradient with depth and to infer the biological degradation of petroleum contaminants	Each sampling round	N/A	Field

TABLE C (CONTINUED)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA

FPTA NO. 4

POPE AFB, NC

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil gas	Oxygen content of soil gas	Electrochemical oxygen meter operating over the range of 0-25 percent of oxygen in the soil gas sample	The concentration of soil gas oxygen is often related to the amount of biological activity, such as the degradation of petroleum hydrocarbons; soil gas oxygen concentrations may decrease to the point where anaerobic pathways dominate	Data are used to understand the oxygen concentration gradient with depth and to determine the presence or absence of aerobic degradation processes	Each sampling round	N/A	Field
Soil gas	Methane content of soil gas	Total combustible hydrocarbon meter using a platinum catalyst with a carbon trap, and operating in the low parts per million volume (ppmv) range	Methane is a product of the anaerobic degradation of petroleum hydrocarbons	Soil gas methane can be used to locate contaminated soil and to determine the presence of anaerobic processes; see discussion of data use for methane in water	Each sampling round	N/A	Field
Soil gas	Fuel hydrocarbon vapor content of soil gas	Total combustible hydrocarbon meter operating over a wide ppmv range	Soil gas hydrocarbons indicate the presence of these contaminants in the soil column	Data used to understand the petroleum hydrocarbon concentration gradient with depth and to locate the most heavily contaminated soils	Each sampling round	N/A	Field
Water	Ferrous (Fe^{+2})	Colorimetric A3500-Fe D	Field only	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese	Each sampling round	Collect 100 mL of water in a glass container; acidify with hydrochloric acid per method	Field
Water	Ferrous (Fe^{+2})	Colorimetric HACH Method # 8146	Alternate method; field only	Same as above	Each sampling round	Collect 100 mL of water in a glass container	Field

TABLE C (CONTINUED)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
FPTA NO. 4
POPE AFB, NC

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total Iron	Colorimetric HACH Method # 8008	Field only		Each sampling round	Collect 100mL of water in a glass container	Field
Water	Manganese	Colorimetric HACH Method # 8034	Field only		Each sampling round	Collect 100 mL of water in a glass container	Field
Water	Chloride	Mercuric nitrate titration A4500-Cl ⁻ C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 250 mL of water in a glass container	Field
Water	Chloride	HACH Chloride test kit model 8-P	Silver nitrate titration	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Oxygen	Dissolved oxygen meter	Refer to method A4500 for a comparable laboratory procedure	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway	Each sampling round	Collect 300 mL of water in biochemical oxygen demand bottles; analyze immediately; alternately, measure dissolved oxygen <i>in situ</i>	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	Protocols/Handbook methods	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system	Each sampling round	Collect 100-250 mL of water in a glass or plastic container	Field
Water	Alkalinity	HACH Alkalinity test kit model AL AP MG-L	Phenolphthalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same groundwater system and (2) to measure the buffering capacity of groundwater	Each sampling round	Collect 100mL of water in glass container	Field

TABLE C (CONTINUED)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
INTRINSIC REMEDIATION EE/CA
FPTA NO. 4
POPE AFB, NC

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Alkalinity	A2320, titrimetric; E310.2, colorimetric	Handbook method	Same as above	Each sampling round	Collect 250 mL of water in a glass or plastic container, analyze within 6 hours	Field
Water	Nitrate (NO_3^{-1})	IC method E300 or method SW9056; colorimetric, method E353.2	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect up to 40 mL of water in a glass or plastic container, cool to 4°C, analyze within 48 hours	Fixed-base
Water	Nitrate (NO_3^{-1})	HACH method # 8039 for high range HACH method # 8192 for low range	Colorimetric	Same as above	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Nitrite (NO_2^{-2})	HACH method #8040	Colorimetric	Substrate for microbial respiration if oxygen is depleted	Each sampling round	Collect 100mL of water in a glass container	Field
Water	Sulfate (SO_4^{-2})	IC method E300 or method SW9056	Method E300 is a Handbook method; method SW9056 is an equivalent procedure	Substrate for anaerobic microbial respiration	Each sampling round	Collect up to 40 mL of water in a glass or plastic container, cool to 4°C	Fixed-base
Water	Sulfate (SO_4^{-2})	HACH method # 8051	Colorimetric	Same as above	Each sampling round	Collect up to 40 mL of water in a glass or plastic container, cool to 4°C	Field
Water	Dissolved sulfide (S^{-2})	HACH method # 8131	Colorimetric	Product of sulfate-based anaerobic microbial respiration; analyze in conjunction with sulfate analysis	Each sampling round	Collect 100 mL of water in a glass container, analyze immediately	Field

TABLE C (CONTINUED)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
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Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Redox potential	A2580 B	Measurements are made with electrodes; results are displayed on a meter; samples should be protected from exposure to atmospheric oxygen	The redox potential of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the redox potential of groundwater may range from more than 200 mV to less than -400 mV	Each sampling round	Collect 100-250 mL of water in a glass container, filling container from bottom; analyze immediately	Field
Water	Methane; carbon dioxide	RSKSOP-175 modified to analyze water samples for methane and carbon dioxide by headspace sampling with dual thermal conductivity and flame ionization detection (also, see reference in note 10)	Method published and used by the U.S. Environmental Protection Agency (EPA) Robert S. Kerr Laboratory	The presence of methane suggests BTEX degradation via an anaerobic pathway utilizing carbon dioxide (carbonate) as the electron acceptor (methanogenesis); a redox potential measurement of less than -200 mV could be indicative of methanogenesis and should be followed by the analysis referenced here; the presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect water samples in 40 mL volatile organic analysis (VOA) vials with butyl gray/Teflon-lined caps; cool to 4°C	Fixed-base

TABLE C (CONTINUED)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
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Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Ethane, ethene	RSKSOP-114 (cont'd)	Ethane and ethene are analyzed in addition to the other analytes only if chlorinated hydrocarbons are contaminants suspected of undergoing biological transformation	Ethane and ethene are products of the biotransformation of chlorinated hydrocarbons under anaerobic conditions. The presence of these chemicals may indicate that anaerobic degradation is occurring			
Water	Carbon dioxide	HACH test kit model CA-23 or CHEMetrics Method 4500	Titrimetric, alternate method	The presence of free carbon dioxide dissolved in groundwater is unlikely because of the carbonate buffering system of water, but if detected, the carbon dioxide concentrations should be compared with background to determine whether they are elevated; elevated concentrations of carbon dioxide could indicate an aerobic mechanism for bacterial degradation of petroleum	Each sampling round	Collect 100 mL of water in a glass container	Field

TABLE C (CONTINUED)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
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Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Aromatic hydrocarbons (BTEX, trimethylbenzene isomers)	Purge and trap GC method SW8020	Handbook method; analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX, which is the primary target analyte for monitoring natural attenuation; BTEX concentrations must also be measured for regulatory compliance; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Total hydrocarbons, volatile and extractable	GC method SW8015 [modified]	Handbook method; reference is the California LUFT manual	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation; data also used to infer presence of an emulsion or surface layer of petroleum in water sample, as a result of sampling	One time per year or as required by regulations	Volatile hydrocarbons—collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2 Extractable hydrocarbons—collect 1 L of water in a glass container; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Polycyclic aromatic hydrocarbons (PAHs) (optional)	GC/mass spectroscopy method SW8270; high-performance liquid chromatography method SW8310	Analysis needed only for several samples per site	PAHs are components of fuel and are typically analyzed for regulatory compliance; data on their concentrations are not used currently in the evaluation of natural attenuation	At initial sampling and at site closure or as required by regulations	Collect 1 L of water in a glass container; cool to 4°C	Fixed-base

TABLE C (CONTINUED)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
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Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Total fuel carbon (optional)	Purge and trap GC method SW8020 modified to measure all volatile aromatic hydrocarbons present in the sample	A substitute method for measuring total volatile hydrocarbons; reports amount of fuel as carbon present in the sample; method available from the U.S. EPA Robert S. Kerr Laboratory Handbook method	Data used to monitor the reduction in concentrations of total fuel hydrocarbons (in addition to BTEX) due to natural attenuation	At initial sampling and at site closure	Collect 40 mL of water in glass vials with Teflon-lined caps; add sulfuric acid to pH 2; cool to 4°C	Fixed-base
Water	Volatile Organics	GS/MS method SW8240		Method of analysis for chlorinated solvents and aromatic hydrocarbons for evaluation of cometabolic degradation; measured for regulatory compliance when chlorinated solvents are known site contaminants	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2	Fixed-base
Water	Dissolved organic carbon (DOC) (optional)	A5310 C	An oxidation procedure whereby carbon dioxide formed from DOC is measured by an infrared spectrometer. The minimum detectable amount of DOC is 0.05 mg/L	An indirect index of microbial activity	Each sampling round	Collect 100 mL of water in an amber glass container with Teflon-lined cap; preserve with sulfuric acid to pH less than 2; cool to 4°C	Fixed-base
Water	pH	E150.1/SW9040, direct reading meter	Protocols/Handbook methods	Aerobic and anaerobic processes are pH-sensitive	Each sampling round	Collect 100–250 mL of water in a glass or plastic container; analyze immediately	Field
Water	Temperature	E170.1	Field only	Well development	Each sampling round	N/A	Field

TABLE C (CONCLUDED)
SAMPLE PACKAGING AND HANDLING REQUIREMENTS
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NOTES:

1. "HACH" refers to the HACH Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. Environmental Protection Agency, March 1979.
4. "Protocols" refers to the AFCEE *Environmental Chemistry Function Installation Restoration Program Analytical Protocols*, 11 June 1992.
5. "Handbook" refers to the AFCEE *Handbook to Support the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS)*, September 1993.
6. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. Environmental Protection Agency, 3rd edition, 1986.
7. "ASTM" refers to the *American Society for Testing and Materials*, current edition.
8. "RSKSOP" refers to Robert S. Kerr (*Environmental Protection Agency Laboratory*) *Standard Operating Procedure*.
9. "LUFT" refers to the state of California *Leaking Underground Fuel Tank Field Manual*, 1988 edition.
10. *International Journal of Environmental Analytical Chemistry*, Volume 36, pp. 249-257, "Dissolved Oxygen and Methane in Water by a Gas Chromatography Headspace Equilibration Technique," by D. H. Kampbell, J. T. Wilson, and S. A. Vandegrift.